Final Technical Report

The development of management strategies for maize streak virus disease

Project Leader

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Contents

Acronyms

ACMVD	African Cassava Mosaic Virus Disease
CIAT	Centro Internacional de Agricultura Tropical
CIMMYT	Centro Internacional de Mejoramiento de Maiz Trigo
DFID	Department for International Development
FAO	Food and Agriculture Organisation
FOSEM	Food Security and Marketing for Smallholder Farmers
GIS	Geographical Information Systems
IDEA	Investment in Developing Export Agriculture
IITA	International Institute of Tropical Agriculture
KWCA	Kawanda Composite A
MFAD	Manpower for Agricultural Development
MSV	Maize Streak Virus
MSVD	Maize Streak Virus Disease
MTEA	Multi-purpose Training and Employment Association
NAARI	Namulonge Agricultural and Animal Production Institute
NARO	National Agricultural Research Organisation, Uganda
NGO	Non-Governmental Organisation
NRI	Natural Resources Institute
OFPEP	On-Farm Productivity Enhancement Programme
PSV	Panicum Streak Virus
RNRRS	Renewable Natural Resources Research Strategy
SA	Situation Analysis
SG 2000	Sasakawa Global 2000
SSV	Sugar cane Streak Virus
Sukura	Sukura Agro Supplies Ltd
UNAFA	Ugandan National Farmers Association
USAID	United States Agency for International Development

Executive Summary

The second phase of the maize streak virus project, whilst continuing to study the important aspects of the epidemiology of the disease, has concentrated on the development of management strategies for maize streak virus disease (MSVD) based on cultural control practices that are acceptable to farmers. These were developed through an understanding of the behaviour of the leafhopper vectors and their role in MSVD spread within maize plots and between maize plantings.

Surveys within villages identified the constraints and potential research needs in the maize growing system and clearly indicated how little farmers and other stakeholders knew about MSVD. The surveys also showed that the lack of a reliable seed supply was a major problem. The project found that, due to cross pollination by local susceptible land-races and farmer seed selection strategies, MSVD resistance was probably being selected out from the only available resistant open-pollinated variety in Uganda (Longe1).

On-farm monitoring showed that the later maize was planted, the higher the incidence of MSVD and that this appeared to explain why there was an indication that women's fields had a higher incidence of MSVD than men's fields, since the women tended to plant later in the season.

The on-farm monitoring also showed that the incidence of MSVD was nearly three times higher in the shade of trees. Subsequent on-station experiments showed that the majority of the principal MSVD vector species, *Cicadulina mbila,* were found in the shade and the majority of the second most important vector, *C. storeyi,* were found outside the shade, effectively separating the two species behaviourally.

Results, from analysing the numbers of vectors and disease incidence within monitoring plots, suggest that MSVD progress is determined by conditions which are present in the crop at an early stage in the epidemic. Thus plots which are characterised by a high initial rate of increase were those in which final incidence was also high. In addition, diseased stands were found to be highly clumped, but new foci were generated throughout the season. These findings are thought to be related to the mating behaviour of the vector where the more mobile males locate the relatively sedentary females. In addition females are thought to prefer maize plants of a favoured height, the distribution of which changes over the season.

Transmission studies showed that there was a large increase over time in the proportions of *C. mbila* carrying MSV in the field and that they also had a much higher proportion of active transmitters than *C. storeyi.* This confirms that *C. mbila* are the most important vectors of MSVD in Uganda.

Experiments have shown that, above a certain density, there was a significant attraction of wild male *C. mbila* to cages containing leafhoppers of the same species. In addition the different sexes of *Cicadulina* locate each other through vibrations transmitted through the substrate on which they are sitting and the acoustic properties of the plants may be an important factor in their selection of plants on which to settle. This may account for the vector's preference for plants of a certain height, which had been shown in previous work by the project, and which would have a considerable affect on the distribution of MSVD within fields.

Intercropping maize with beans or millet results in a reduction in male *Cicadulina* activity within the intercropped crop but the catches of females are not reduced. Reductions in MSVD incidence and competition effects on yield in the intercropped maize were too variable to produce any clear recommendation but might merit further examination.

Taking into account the complexity of the farmers' situation in the study areas the project has improved farmers' knowledge of MSVD so that they can make informed decisions about managing the disease. This has been through the involvement of local extension staff, on-farm training and the production of information leaflets.

A local variety of maize in one area studied showed vector resistance and this was subsequently confirmed when on-station trials of different varieties of maize were carried out. Other maize varieties have shown varying degrees of vector resistance. In addition to the level of severity (virus resistance), observations of proportions of plants infected with MSVD are made as a routine reading as part of maize breeding/selection work. However, selection has primarily been done for virus resistance. The source of resistance to MSVD currently being exploited by plant breeders is one in which infected plants develop only mild symptoms and suffer only slight yield loss. Ugandan maize breeders have developed one such open-pollinated variety released as Longe1. Selection of naturally infected, but mildly affected plants for streak resistance has the danger of selecting against vector resistance since it has been shown that *Cicadulina* appear to actively select plants on which to settle. Their preferred choices tend to be the shorter, weaker plants in a stand and these may be in this condition as a result of earlier MSV infection. It is suggested therefore that artificial streak infection be used for MSV resistance selection by maize breeders and that this is best done with the vectors confined in pots to challenge individual plants and not by using a release method where the vectors have the chance to select the plants on which to settle.

An end-of-project workshop was held and well attended. The proceedings have been submitted to CPP management in final draft form for their input prior to distribution to participants and interested parties. Seed quality and availability were considered by all workshop participants to be major factors to be included in the development of management strategies for MSVD.

The unreliability of available maize seed was a major constraint to farmers producing good yields from their maize crop. Through collaboration with village groups, extension officers and NGOs it has been possible to train farmers in the study villages and to provide them with small amounts of high quality Longe1 breeders' seed. The project has begun exploring the idea of empowering farmers to produce their own seed through selection and controlled pollination. The farmers have been very enthusiastic about taking up this technique and a follow-up of this work has been agreed.

Background

Studies on the epidemiology of Maize Streak Virus Disease (MSVD) have been limited to Zimbabwe, Mauritius, Nigeria and Zaire (see Rose 1978; Dabrowski, 1985), but these areas represent only some of the agro-ecological zones in which MSV can be epidemic. No comparable study had been attempted in the mid-altitude agro-ecological zones, typified by maize production systems in Uganda. As a result the Maize Streak Virus Project R5246 (A0173) was commissioned in 1993 with a field base in Uganda and research has focused on determining the role of the leafhopper vectors in the epidemiology of the disease.

Monitoring sites were established in the major maize growing regions in Uganda and disease incidence, *Cicadulina* abundance and species composition have been monitored regularly to develop a pattern of disease incidence and severity over time in different agro-ecological zones. Data were incorporated into a GIS developed through R5360 (A0260) to investigate the relationship between incidence of key insect-vectored plant virus diseases and topography and meteorology in Uganda. Studies on the pattern of MSVD spread within maize plots were undertaken to clarify the relative importance of primary and secondary sources of inoculum in the spread of the disease. Modelling techniques were used to characterise disease progress in maize plantings, to quantify spread parameters and the effects of ecosystem variables on rates of spread, and to analyse the relationship between disease progress and vector abundance. The aim of the modelling work was to develop a system for predicting MSVD-induced losses in advance, so that timely preventative measures might be undertaken.

Further RNRRS-funded research on MSV was carried out under project R5237 (X0127) on the identification and characterisation of economically important strains of maize streak geminivirus (October 1989 to September 1992), based at the John Innes Institute. The project results showed that in Africa there are at least three geminiviurses affecting monocotyledonous plants which have a common ancestor; maize streak virus (MSV), panicum streak virus (PSV) and sugar cane streak virus (SSV). Two other isolates may also prove to be sufficiently different to warrant classification as distinct viruses.

Detailed studies on the behaviour of *Cicadulina* revealed that they are present on wild grasses throughout the year. They enter maize plots primarily when the plants are at a particular growth stage, 30-40 cms high, irrespective of the time of year, seemingly to utilise the more uniform habitat as an arena for mate-seeking. Studies in collaboration with the University of Wales showed that *Cicadulina* males and females locate each other though species-specific male and female abdominal vibrations transmitted and detected through the maize plant. Most disease spread within plots appears to be caused by the highly mobile males moving throughout maize plots in search of females. The females are more sedentary during their comparatively short period within the crop and are principally found up in the canopy of maize (particularly the whorls) whilst the males move around closer to the ground.

Preliminary trials were undertaken, utilising knowledge of the vectors' behaviour, to try and minimise disease spread through the use of low-growing intercrops. Finger millet or beans, both important crops to Ugandan farmers, have been tested as intercrops and initial results indicated up to 52% reduction in the incidence of MSVD. Further work was needed to develop appropriate intercropping systems that minimise disease spread, yet are acceptable and profitable for the maize farmers in the region. The time period when maize plants are most attractive to *Cicadulina* is quite short and preliminary data have also indicated that increased synchrony of planting within an area, shortens the period of attraction to

Cicadulina and therefore the potential for the introduction of inoculum sources into maize fields.

The second phase of the project has sought to develop these aspects of the research and to integrate them with the use of MSV-tolerant varieties, as they become available through the Uganda Maize Programme, into an integrated management strategy for the disease.

The project team was based at the Namulonge Agricultural and Animal Production Research Institute (NAARI), 26 km north of Kampala, Uganda.

Project Purpose

The following Project Objectives and Project Outputs were specified for the project:
To increase maize yields in subsistence and cash crop growing areas by developing and promoting sustainable strategies to manage MSVD which are acceptable to farmers and are based on knowledge of vector behaviour and sound epidemiological principles.

MSVD vectored by *Cicadulina* leafhoppers is recognised as a major constraint in maize production throughout sub-Saharan Africa. Although MSV-tolerant maize varieties are being developed through IITA, CIMMYT and the Ugandan Maize Programme they are not yet widely available in eastern Africa. Farmers continue to follow traditional practices using their own seeds for subsequent plantings rather than purchasing varieties or hybrids produced on seed-farms. This results in dilution of MSVD-tolerance in the maize gene pool within a region due to cross-pollination with local, susceptible varieties. Alternative, low cost means of reducing the impact of MSVD are therefore required. The project has developed and evaluated management strategies based on cultural control practices arising from knowledge of vector behaviour gained during the strategic phase of the research on MSVD. Project outputs include advice on intercropping techniques, farming practices to minimise losses due to MSVD and identification of useful traits for vector resistance to be incorporated into maize screening programmes.

Planned Project Outputs

1. Management strategies for MSVD based on cultural control practices that are acceptable to farmers, and are developed through an understanding of the behaviour of the leafhopper vectors and their role in MSVD spread within maize plots and between maize plantings.

2. Information on maize crop characteristics associated with MSV-vector resistance available for incorporation in screening programmes.

Research Activities

1. Socioeconomic studies and subsequent follow-ups

1.1 *Socio-economic surveys to assess farmers' perceptions of MSVD.*

Rationale

One area in which researchers currently have limited information is farmers' knowledge of MSVD. A brief review of reports documenting previous socio-economic/ survey work under the maize programme has been carried out. This review revealed a reconnaissance/ diagnostic survey in Masaka and Masindi districts (1988), a pests and diseases incidence/ agronomic practices survey in Masaka, Kasese, Masindi and Mubende districts(1990), and adoption/ impact studies of recommendations from the MFAD project (1993) and of Longe1 and recommended practices (1995).

The overall aim of the socio-economic activities was to involve a wider range of stakeholders, particularly the primary beneficiaries (i.e. smallholder maize growers) in the research process. This was based on the assumption that this would guide the research towards client-oriented interventions.

Methodology

Maize is an important crop in both highland and mid-altitude areas of Uganda. However, MSVD is not generally a problem in high altitude areas and it was decided to focus on mid-altitude locations in eastern Uganda. The main criterion for selection of villages was that maize should be an important crop.

Village-based research was initiated through a Situation Analysis (SA) of four villages in what were then two districts (Iganga and Tororo) in SE Uganda (Table 1). The aim of the SA was to improve researcher understanding of the knowledge and situation of farmers growing maize, with a view to developing an on-farm research programme contributing towards the development of options for the control of MSVD.

DISTRICT	VILLAGE	SUB-COUNTY	COUNTY
Tororo:	Kisoko	Kisoko	West Budama
	Ajuket*	Busitema	Samia Bugwe
Iganga:	Mamukubembe	Bukanga	Luka
	Bugode	Baitamboga	Bunya

* During the study period Ajuket came under the new District of Busia

Table 1. Villages visited the situation analysis during the project

The scope of the study was initially developed by the study team (see below), together with Dr Denis Kyetere who is the Head of the National Cereals Programme based at Namulonge Agricultural and Animal Production Research Institute (NAARI). Follow-up discussions and a field visit helped to further develop site selection, farmer selection, a checklist and techniques to address checklist points (See Appendix 1). A core multi-disciplinary team of seven researchers carried out field activities:

Bill Page	Field Manager/ Entomologist, NRI
Dr Richard Gibson	Virologist, NRI
Dr Justice Imanywoha	Breeder, National Cereals Programme
Twaha Kalule	Entomologist, National Cereals Programme
Dr Joseph Kikafunda	Agronomist, National Cereals Programme
Richard Lamboll	Socio-economist, NRI
Mary Mugisa Matetika	Social scientist, National Beans Programme

In each village extension officers and others were involved in the research activities.

With regard to farmer selection, the main aim was to involve a broad cross-section of people. Given limitations on time, this was achieved through discussions being held with separate groups of elders, women and men in each village. The checklist was used to guide discussions and various participatory techniques were used to facilitate the process. The information collected was summarised and discussed by the study team both during fieldwork and in follow-up meetings at NAARI.

The SA was followed-up by surveys focusing on MSV knowledge and dissemination. The main areas of discussion were, ownership, control and access to resources, seed, use of maize and sources of knowledge of maize. NGOs, programmes and projects relevant to maize production in the villages were also identified and in some cases discussions were held.

Further socio-economic research focused particularly on type, sources and management of seed.

The village-based research programme moved from a focus on four villages to the two in Iganga district. This enabled a better rapport to develop with a group of farmers in each village. Seminars were held in each village to provide more information on MSVD and this was re-enforced during visits to monitor plots for the disease.

Outcomes

In general, maize became an important cash crop in the 1960s (Tables 2 and 3). Factors influencing the expansion of maize were not fully discussed in the villages. However, reasons suggested by the study team include government campaigning (including through young farmer groups), the introduction of rust resistant varieties and a good market for the crop.

A major characteristic of the farming system in each of the study villages was the wide range of crops being grown (Table 4). The majority of crops are grown for both food and cash and in common with many parts of Uganda, the system in all the study villages is undergoing change.

Maize is not the preferred food in any of the study locations (see Appendix 2) and much of the expansion of the crop can be attributed to the availability of a market. However, with the long-term decline in banana production and the more recent impact of African cassava mosaic virus disease (ACMVD) on cassava output, maize has become important as both a source of food and cash.

The main practices involved in maize production are essentially the same in all the study villages. They are clearing land, burning of trash, planting, weeding (usually twice) and harvesting (green and dry). The timing of activities is largely determined by the bi-modal rainfall pattern, which results in two main planting seasons per year (see Appendix 3). However, the onset and amount of rainfall vary according to a number of factors including topography and distance from Lake Victoria. These variations (each village effectively having a different rainfall pattern) only became apparent during field activities and emphasises the importance of an appreciation of local environmental factors and their potential influence on MSVD.

EVENT/DATE			FOOD CROPS GROWN & CHANGES		CASH CROPS GROWN & CHANGES		LIVESTOCK		FARMING PRACTICES	
KISOKO	AJUKET	DATE	KISOKO	AJUKET	KISOKO	AJUKET	KISOKO	AJUKET	KISOKO	AJUKET
FAMINE		1918	FINGER MILLET, BANANA, COWPEAS, SWEET POTATO, YAMS, GROUNDNUTS, SOME SORGHUM (brewing), LOCAL VEGETABLE (akeyo), CUTTINGS OF CASSAVA ARRIVED IN 1ST WORLD WAR, LITTLE MAIZE (eaten green)	FINGER MILLET, BANANA, COWPEAS, SWEET POTATO, GROUNDNUTS, SORGHUM, CASSAVA, SIMSIM, BAMBARA NUTS. NO MAIZE	COTTON ONLY		SHEEP, CATTLE, GOATS, POULTRY, PIGEONS		HOES AND PANGAS	HOES AND STICKS
RAILWAY REACHES AREA		1926								
	FAMINE AND LOCUSTS	1930-32								
FIRST TRAIN & PLAGUE		1933								
LOCUSTS		1936-38	RED BEAUTY GROUND-NUTS INTRODUCED							
		1940	RICE INTRODUCED BY THE INDIANS	BEANS INTRODUCED	RICE				OX PLOUGHS INTRODUCED	
	FAMINE	1942		FIRST MAIZE						
FAMINE		1943-44								
	FAMINE	1948		FIRST RICE		RICE BECOMES CASH CROP (selling to Indians)				
		LATE 1950's	BEANS INTRODUCED							
HEAVY RAINS & TAX RESISTEMCE		1960	GROUNDNUTS AND CASSAVA EXTENSIVE MAIZE ALSO INCREASING		GROUNDNUTS			PIGS INTRODUCED, DUCKS COME IN WITH CATHOLIC PRIESTS	TRACTOR PLOUGHING INTRODUCED THROUGH THE TRACTOR HIRE SERVICE	OX PLOUGHS INTRODUCED
	ARMYWORM	1962								
		1960's		RED GROUND NUTS COME IN . 1963 STRIGA		CABBAGES				
	AGRICULTURAL STAFF IN AREA	1964								TRACTOR HIRE FOR A SHORT TIME
	FIRST GROUP FROM VILLAGE TO DISTRICT FARMER INSTITUTE	1968		MAIZE, RICE CASSAVA, SOYA BEANS ALL BECOME IMPORTANT CROPS		MAIZE, RICE CASSAVA, SOYA BEANS ALL BECOME IMPORTANT CROPS				
		1970			RICE BECOMES A CASH CROP, AS DOES MAIZE		EARLY 1970's PIGS BRED FOR CASH			
HAILSTONES EACH YEAR		1974-81				1979 IRISH POTATO GROWN SMALL SCALE				
FAMINE		1980								
FAMINE		1985								
		1989				SUNFLOWER				
		1990	INTRODUCTION OF EGOLA 1 GROUNDNUTS						SPRAYING GROUNDNUTS AND VEGETABLES BEGAN AND PLANTING IN ROWS DUE TO PESTS AND DISEASES	
ARMYWORM & HAILSTONES		1993	CASSAVA BEGAN TO REDUCE DUE TO DISEASE							
GOOD RAIN DISTRIBUTION		1996		YIELD REDUCTIONS DUE TO SOIL FERTILITY						

Table 2. Changes in farming systems in Kisoko and Ajuket villages (Tororo district)

EVENT/DATE			FOOD CROPS GROWN & CHANGES		CASH CROPS GROWN & CHANGES		LIVESTOCK		FARMING PRACTICES	
MAMUKUBEMBE	BUGODE	DATE	MAMUKUBEMBE	BUGODE	MAMUKUBEMBE	BUGODE	MAMUKUBEMBE	BUGODE	MAMUKUBEMBE	BUGODE
FAMINE		1917	BANANA (main up to 1950's), GROUNDNUTS, SWEET POTATO, MILLET, YAMS, BAMBA NUTS, PAWPAW, PUMPKINS, SIMSIM, GREEN & BLACK GRAMS, GUAVA, NUMBU (root crop like Irish potato)	BANANA, GROUNDNUTS, SWEET POTATO, MILLET, YAMS, BAMBA NUTS, PUMPKINS, SIMSIM, GREEN & BLACK GRAMS, CASSAVA (drought reserve), MANGO, SWEET BANANA, PASSION FRUIT (hard type)	COTTON ONLY		GOATS, SHEEP, CATTLE, CHICKENS KEPT IN SMALL NUMBERS, HUNTING DOMINANT		HOES WITH SPIKES AND WOODEN STICKS	
FORCED LABOUR	FAMINE (BIKUTYA)	1920-21				1920's-30's BARTER				
	WILD PIGS DESTROY CROPS	1925								
LOCUSTS	ARMYWORM THEN LOCUSTS	1938-39 LATE 30'S			ORANGES AND PINEAPPLES CAME					
	FAMINE (BIKAPU)	1931		MAIZE (red and small) GROWN A LITTLE						
	BAD TSETSE	1930-35								
SMALL BITING FLIES		1932-36	1939 SUGAR CANE					1930's PIGEONS	1938 MODERN HOES INTRODUCED	
FAMINE (SOYA BEAN FAMINE)		1943-44 1941	APPROX. 1944 MAIZE STARTED COMING IN (small and red seeds) ALSO SOYA BEAN CAME IN	SOYA COMES IN, SMALL PATCHES OF RICE				1940'S DUCKS		
	DRIVING OF WILD ANIMALS INTO RESERVES	1945	CASSAVA COMES IN (forced to grow)			MAIZE BECOMES CASH CROP		1950's DOMESTIC ANIMALS BECOME MORE IMPORTANT BECAUSE OF DECLINE OF GAME		1946 NEW HOES WHICH WERE SHORTER AND THICKER
	SMALL BITING FLIES	1952	BEANS COME IN, 50's BANANA REDUCES, 1958 GREEN GRAMS REDUCE	LATE 50's GREEN GRAMS AND BAMBA NUTS REDUCED	COFFEE CAME IN	50's SOYA BEAN, GROUNDNUTS AND SWEET BANANA BECOME COMMERCIAL. COFFEE GROWING STARTS				
HEAVY RAINS		1960-61 1961	1960 LOT OF MAIZE AND SUGARCANE BEING GROWN		1960 MAIZE AND SOYA BECOME CASH CROPS, COFFEE BECOMES MORE IMPORTANT, GROUNDNUTS BECOME COMMERCIAL	1960'S ISOLATED COCOA GROWN			1960 TRACTORS USED (THROUGH HIRE SCHEME)	
	BAD VIRUS DISEASE OF COTTON DEPT OF AG. BRING CHEMICALS	1964	1965 BAMBA NUTS REDUCE, 1967 CABBAGES INCREASE , 1968 SIMSIM REDUCES	64-64 MAIZE BECOMES ONE OF THE MAJOR CROPS	1967 CABBAGES AND OTHER VEGETABLES SOLD		PIGS, PIGEONS, RABBITS, AND DUCKS INTRODUCED AS A RESULT OF THE YOUNG FARMERS GROUP			1963 TRACTOR HIRE AVAILABLE FOR SHORT TIME
	FAMINE	1969-70	1973 BEANS INCREASE	1970's BANANA REDUCES, CASSAVA AND SWEET POTATO INCREASE, 1971 YAMS REDUCE DUE TO ROOT ROT	BEANS, SUGARCANE AND SWEET POTATO BECOME CASH CROPS		1970's TURKEYS			
FAMINE (KYADA)		1980 1979-80		60's-80's MILLET REDUCES AS LESS COTTON GROWN (good rotation crop)	1976 COTTON GROWING STARTS REDUCING	COTTON REDUCES		LATE 70's PIGS INTRODUCED		

Table 3. Changes in farming systems in Mamukubembe and Bugode villages (Iganga district)

MAMUKUBEMBE AND BUGODE (CONTINUED)										
EVENT/DATE			**FOOD CROPS GROWN & CHANGES**		**CASH CROPS GROWN & CHANGES**		**LIVESTOCK**		**FARMING PRACTICES**	
MAMUKUBEMBE	BUGODE	DATE	MAMUKUBEMBE	BUGODE	MAMUKUBEMBE	BUGODE	MAMUKUBEMBE	BUGODE	MAMUKUBEMBE	BUGODE
POOR MARKET PRICES		1980-90's	1985 GROUNDNUTS REDUCE, 1990 RICE INCREASES		1980's BANANA GROWN IN SMALLER QUANTITIES (due to weevils)	RICE INCREASES		1980's EXOTIC DOMESTIC ANIMALS REPLACE LOCAL TYPES	TRACTORS BEGAN DISAPPEARING	
INVASION OF CASSAVA MOSAIC		1995 1993		CASSAVA REDUCES	1990-93 PASSION FRUIT INTRODUCED			90's REDUCTION IN LIVESTOCK DUE TO LAND SHORTAGES		
	LOTS OF DISEASES ON VARIOUS CROPS	1993-96								
		1996	GRAMS, GROUNDNUTS AND BAMBA NUTS SELDOM GROWN	LITTLE CASSAVA	LITTLE COTTON GROWN				TRACTOR STILL AVAILABLE BUT COSTLY. NO OX PLOUGHS	

Table 3 (cont.)

	TORORO		IGANGA	
Crop	**Kisoko**	**Ajuket**	**Mamukubembe**	**Bugode**
Amaranths		√	√	√
Avocado			√	√
Bambara nut	√			
Bananas	√	√	√	√
Beans	√	√	√	√
Cabbage	√	√	√	√
Cassava	√	√	√	√
Coffee	√	√	√	√
Cotton	√	√	√	
Cowpea	√	√	√	√
'Curry powder' plant	√		√	
Egg plant	√		√	√
Entula (aubergine-like)			√	√
Finger millet	√	√	√	√
Ginger			√	√
Green pepper	√			
Greengram		√	√	√
Irish potato		√	√	√
Jackfruit	√	√		
Jobyo (leafy vegetable)				√
Maize	√	√	√	√
Mango			√	√
Nakati (leafy vegetable)			√	√
Onion	√	√		√
Oranges		√	√	
Passion fruit	√		√	√
Pawpaw			√	√
Pineapple		√	√	√
Pumpkin	√		√	√
Red pepper			√	
Rice	√	√	√	√
Simsim	√	√	√	√
Sorghum	√	√	√	√
Soya bean	√	√	√	√
Sugar cane	√		√	√
Sunflower	√			
Sweet potato	√	√	√	√
Tomatoes	√	√	√	√
Yam	√		√	√

Table 4. Crops reported in survey currently growing in study villages

There is little clearing of mature bush vegetation. In most cases land is too scarce for sufficient time to allow such vegetation to grow. Once land has been cleared it is used for a number of years (4 or 5 years in Iganga villages) until yields become too low for cultivation to be worthwhile. The majority of the time, clearing refers to weed growth between one planting season and another.

Land preparation varied significantly between the two districts. In Tororo the ox plough is relatively common, whereas in Iganga most farmers just use a hoe.

Men's and women's groups gave different answers regarding who carries out the work. Men suggested all the family is involved in most of the activities. Women presented a different picture, with men making less of a contribution. One issue that came out in at least one village was that there were men's maize fields (primarily for cash) and women's (mainly for food). There was a strong suggestion that frequently women were expected to work in men's fields, but men did not work in their wives' fields. This resulted in activities being carried out later on women's fields which has implications for the management of pests and disease problems (see below).

Hired labour is not common. Group labour was reported, but it was not clear how prevalent it is.

In all villages, most farmers intercrop maize. They do so primarily to get more food from the same land (which saves land but perhaps more importantly saves the work of opening new land) and to a lesser extent to reduce the effect of one crop failing. A few said that it may improve soil. In all villages, beans are the preferred intercrop for main crop maize and soya beans the next. Groundnuts are also grown with maize but the maize is then the minor crop and widely spaced. Beans were said to be mostly planted 1-2 weeks after maize has germinated because they otherwise compete strongly with the maize, and planting is avoided in the heaviest rains. Soya beans are mostly planted when maize is planted because they have a long growing season and like plenty of rain. Intercrops are generally planted between maize lines.

In all villages, most farmers used home-saved seed, known as "local" in Tororo District or "Musoga" in Iganga; only a few bought seed and then only occasionally. However, they still called home-saved seed of specific varieties by their original names e.g. 'Longe1' or, even more confusingly, "hybrid" (Table 5). Bought-in seed had problems. Price was the main one (price at Masindi Seed Project farm was 600/-/kilo for Longe1 but may reach 1200/- in the village), but, poor quality (often cracked) seed and poor germination and fake varieties are also important problems. During the project we experienced some of these problems with seed obtained for our experiments.

	Kisoko	Ajuket	Mamukubembe	Bugodi
Longe1 (1)	3	T/D	3	3
Hybrid	3H622	?	T/D	T/D
Popcorn	3	3		
Spindi		3		
'Local'*	3	3	3	3

* See text; T/D - grown by farmers as part of trial or demonstration

Table 5. Types of maize grown in the study villages

Greater detail on maize being grown was collected after the village-based research programme moved its focus from four to two villages (Appendix 4, also see below).

In all villages, small or medium (but not large) maize cobs are often harvested for roasting; consequently, such cobs are not used for seed. In all villages, the selection of cobs for seed is done after the parent plant is dead i.e. at harvest in Tororo and at threshing or at planting time in Iganga, so no knowledge of whether the parent plant was MSV-infected is possible. In Tororo, seed was taken from large, evenly filled cobs with large white seeds. In Iganga, cob size was less important but seeds again had to be large and white. At all villages, only enough cobs to plant the new crop were saved. Generally, both men and women select seed. Seed tended to be stored in the smoky areas under the roofs of houses.

A wide range of constraints in maize production were identified (Appendix 5). An overall ranking was carried out on the basis of frequency of reporting (Table 6). Using this system, the ten most important constraints were as follows: storage problems, stalk borers, MSVD, labour, termites, poor soil fertility, marketing (prices received), maize seed (cost, poor seed, low yielding), molerats and lack of inputs.

MSVD (or at least the symptoms) was reported by at least one group in each village as one of their ten main problems. Some constraints were location specific e.g. *Striga* in Ajuket and monkeys in Namukubembe and Bugodi. Others appeared to be gender specific, with women in Namukubembe and Bugodi reporting drudgery and, on the whole, men (in every village) reporting declining soil fertility as major constraints.

People were also asked how the problems were currently being addressed in the village and what further possible interventions could be made. This brought a wide range of responses (Appendix 5). In Ajuket, for example, the men's group knew that crop rotation, weeding and manure were possible approaches to controlling *striga*. In Namukubembe and Bugodi ox-ploughs and wheelbarrows were suggested as ways of addressing drudgery. These and other responses may give some pointers for how researchers and farmers may jointly develop options for interventions to address some of these constraints. In other examples farmers were unaware or wrong about the causes of problems. In these cases improving farmer understanding of a problem would at least allow them an opportunity to start addressing the constraint. MSV would appear to be in this category.

SUMMARY OF CONSTRAINTS ON MAIZE FARMERS													
	KISOKO			AJUKET			MAMUKUBEMBE			BUGODE			TOTAL MENTIONS
PROBLEM	ELDERS	WOMEN	MEN	ELDERS	WOMEN	MEN	ELDERS	WOMEN	MEN	ELDERS	WOMEN	MEN	11
STORAGE PROBLEMS (PESTS)	✓		✓(5)	✓	✓	✓(6)	✓	✓	✓(6)		✓	✓(8)	10
STALK/STEM BORERS	✓			✓	✓	✓(1)		✓		✓	✓	✓(7)	8
MAIZE STREAK VIRUS (LOW YIELDS)	✓			✓	✓	✓(3)	✓	✓	✓(4)		✓		8
LABOUR (COST, SHORTAGES)	✓		✓(4)	✓	✓	✓(7)	✓					✓(10)	7
TERMITES				✓	✓	✓(8)	✓	✓			✓	✓(4)	7
POOR SOIL FERTILITY	✓		✓(3)		✓	✓(5)			✓(1)			✓(6)	6
MARKETING (PRICES RECEIVED)			✓(6)				✓	✓	✓(8)	✓	✓		6
MAIZE SEED (COST, POOR SEED, LOW YIELDING)			✓(1)			✓(9)	✓		✓(2)			✓(2)	5
MOLERATS						✓(8)	✓	✓			✓	✓(5)	5
LACK OF INPUTS			✓(2)	✓			✓			✓			4
TRANSPORT (POOR ROADS, LACK OF)			✓(7)				✓		✓(9)	✓			4
DROUGHT					✓		✓	✓		✓			4
BIRDS (EATING SEEDLINGS, ATTACKING COBS)								✓	✓(5)	✓	✓		4
MONKEYS								✓		✓	✓	✓(3)	4
STRIGA				✓	✓	✓(2)							3
POOR GERMINATION								✓	✓(3)		✓		3
ROTTEN GRAIN (EAR ROT)						✓(4)				✓			2
DIFFICULTIES IN SHELLING							✓		✓(7)				2
DRUDGERY (LACK OF TOOLS TO DO THE JOBS)								✓			✓		2
LAND SCARCITY							✓					✓(1)	2
THEFT IN THE FIELDS												✓(9)	1
SMUT											✓		1
LODGING											✓		1
HAILSTONES										✓			1

✓(1) = MENTIONED (✓) AND RANKED 1ST (1)

Table 6. Constaints on maize growing. Ranking was carried out on the basis of frequency of reporting

In almost all cases MSVD symptoms were first noticed in the 1980s or 1990s (Table 7). In three of the villages at least one group reported that the problem had become serious in the last two or three years. No name was identified for the disease in any of the villages. In describing the symptoms some farmers explained that the plant went yellow or white.

Few of the farmers realised that the symptoms of MSVD were caused by a disease. Nobody was able to identify the leafhopper vectors that transmits MSV. A number of other insects were suggested as being possible causes of the problem.

The single most common explanation for MSV was related to soil and in particular fertility (Table 7). The weather (drought) and the seed were mentioned by a number of groups. The men's group in Namukubembe suggested that the problem related to the continuous cropping of maize that had become common in the village.

The maize planted in the second cropping season is generally more badly infected by MSV than that in the first. Farmers often second-plant maize after maize.

Farmers' perceptions of seed according to MSVD-resistance varied considerably. However, hybrid was always ranked the lowest (Table 7). In the six groups where this information was collected, three ranked Longe1 first and three ranked local first. Because of farmers' perceptions of the varieties being grown (see below) it is not possible to know what exactly is being described as 'Longe1' or local. The early maturity of Longe1 was appreciated but farmers complained about the quality of the grain, its softness and susceptibility to post-harvest pests and cob rot in wet weather. There was also a perception that Longe1 competes poorly with weeds, perhaps because it is of short stature.

From the extension literature available, it would appear that the main 'impact point' regarding MSVD is the recommendation to plant Longe1 as a resistant variety and to buy in fresh seed after two years. It is not clear what other knowledge extensionists have of MSVD.

		Cause/ associated factors						Ranking of seed according to MSV resistance		
VILLAGE/ Group	**Year MSV noticed**	**Pest/Insect**	**Soil fertility**	**Weather**	**Seed related**	**Disease**	**Other**	**Local**	**Hybrid**	**Longe1**
KISOKO										
Elders	?		√					?	2	1
Women					√		Came from soil. Worms	1	3	2
Men	1990			√(drought)			Land over-use. 'Curse!'	1	3	2
AJUKET										
Elders	(1993)		√			√(in soil)		Almost entirely local seed used		
Women	1991(1994)*	√								
Men	1993									
M'BEMBE										
Elders		√	√	√	√			2	?	1
Women	1980	√	√	√(drought)				2(Kawanda	?	1
Men	1981/83(1994)				√(undried)		Shade. Continuous planting			
BUGODE										
Elders	1985(1993)		√	√(sun)		√	Not weeding			
Women	70s/early 80s	√					Came from soil	1	?	2
Men	1990	√					Undried seed suspected,			
							but disproved by farmer+			

* Years in brackets indicate when MSV became a significant problem + One farmer thoroughly dried seed before planting, but maize was still infected by MSV

Table 7. Farmer Perceptions of MSV

The way people learn clearly varies according to a number of factors depending on their personal characteristics and individual circumstances. A number of sources of knowledge with respect to maize were identified in the four villages (Table 8).

Source	Kisoko	Ajuket		Mamukubembe	Bugodi
	n =4	Women	Men	n=3	n=3
Home/ parents	3	3		1	3
Retired agric. officer	2				1
Shop selling seed	1				
Instructions on seed packet	1				
Discussion in village / neighbours	3				
Extension workers	2	3	3	2	
NGOs	1			2	
Contact farmers		3			
Group		3	3?	?	3
Direct observation			3		
Radio			3		
Village leaders			3		

Table 8. Sources of knowledge with respect to maize

The information collected gives some indication of the diversity of possible sources of knowledge, although not the process by which farmers are receiving and assimilating information in order to make decisions about farming activities.

Some observations may be made. Government policy is aimed at reducing public sector involvement in agriculture, including the extension service. There are no extension staff operating below the level of sub-county. Frequently, this means extension staff are expected to facilitate the creation of farmer groups and disseminate information through other farmers. Such groups are active in Bugodi and Mamukubembe, although in the latter case groups were not mentioned as a source of knowledge. This may be because the programme providing inputs/ training was named (e.g. IDEA) rather than the group which was acting as a facilitator. There is also some indication that the private sector has a role in providing information to farmers, e.g. a shop selling seed in Tororo (although a member of the Extension Service owned it). Retired extension workers were also cited as sources of knowledge in two of the villages.

In response to farmer requests, and prior to the beginning of the first season's planting in January 1997, meetings were held in all four, study villages to explain MSVD in some detail. The local agricultural officers attended the meetings. Farmers were also introduced to the idea of monitoring surveys to examine various aspects of farm management with regard to the incidence of MSVD. Attendance (totalling 236 farmers) and the methods used are summarised in Appendix 6.

A number of NGOs/ projects/ programmes were identified as having an interest in aspects of maize production (Table 9). The government extension service provides support through officers based at the sub-county level and above.

	Kisoko	Ajuket	Mamukubembe	Bugodi
Adhola SSC (CCF)	3			
OFPEP	3			
Sasakawa Global 2000	3	3	3	?
IDEA			3	3
UJIMA			3	?
Makerere University				3

Table 9. NGOs and projects active in maize production work in the study villages.

Influence on direction of research

From the constraints identified there were clearly a large number of potential research needs, some of which (e.g. storage problems) have at least started to be addressed. It was beyond the scope of this study to consider constraints other than MSV in any further details. However, many of these constraints are inter-related and if resources are available there is a strong case for approaching these problems (particularly on-farm) with an integrated approach.

The research needs and activities that have been identified through this study relating to MSVD are summarised in the Table 10.

Research Need	**Activity**
1. Influence of farmer practices on MSV incidence. Including: What maize seed is planted ? How maize is planted ? When maize is planted ? How maize is managed after planting e.g. roguing, gap filling, weeding ?	1.1 Field Monitoring survey: Physical observation in fields Interviews with farmers 1.2 On-station trials: Roguing Gap filling Inter-cropping - time of planting in relation to time maize is planted; Soya as an inter-crop
2. MSVD Knowledge and dissemination Who is making information available to farmers ? What is their knowledge of MSVD ? What is an appropriate level of knowledge ?	2.1 Personal interviews with agents of dissemination e.g. Government extension service, NGOs
3. MSVD resistant variety more acceptable to farmers	3.1 Farmer variety preference monitoring 3.2 Breeding of varieties
4. Seed selection strategies	4.1 Farmer training 4.2 On-farm trials
5. Environmental factors determining MSVD incidence	5.1 Analysis of existing data

Table 10. Project-identified research needs and activities relating to MSVD

Influence of farmer practices revealed the importance of shade as a factor influencing MSVD. It also became clear that farmers were using a range of seed that was being described as Longe1. Both these points have been addressed in the project (see below).

Research on MSVD knowledge and dissemination clearly indicated how little farmers and other stakeholders knew about MSVD.

The lack of a reliable seed supply was identified as a major problem.

Farmer seed selection strategies were probably selecting out MSVD-resistance from Longe1.

Two main strategies that emerged for managing the disease were:

- Given the complexity of the farmers' situation, improve farmers’ knowledge of MSVD so that they can make informed decisions about managing the disease. This includes information regarding practices which are likely to encourage (e.g. planting under shade) and discourage (e.g. planting early) MSVD. This has been addressed in the project through the involvement of local extension staff and on farm training and the production of leaflets (see below).

- The unreliability of available maize seed was a major constraint to farmers producing good yields from their maize crop. It was beyond the scope of the project to address such institutional problems directly. However, through training farmers in the study villages and providing them with small amounts of high quality Longe1 seed from Namulonge, the project began to explore the idea of empowering farmers to produce their own seed through selection and controlled pollination (see below).

1.2 *Effect of seed selection by farmers tested*

Simulation on-station of farmer selection

These experiments were conducted to assess the effect of traditional farmer seed selection practice on MSV resistance in the released variety Longe 1. They examine how this might interact with the effects of cross-pollination by local varieties and as well as selection within Longe 1

Selection within Longe 1. Longe 1 seed obtained from the Uganda Seed Project was planted in a plot 15 m wide by 90 m long, single spaced at 0.3m intervals in rows 0.75m apart on giving a total plant population of about 6,000. The plot was located at the International Institute of Tropical Agriculture (IITA) Regional Research Station Sendusu farm in Uganda at NAARI. This farm was chosen because no maize was grown there (the plot was surrounded by bananas and yams) and the plot was >0.5 km from other maize crops. Plants were scored for infection and severity at maturity on 17th December (MSVD develops only on growing leaves (Gibson & Page, 1997)) and grain yields recorded. A 0 - 5 scale devised by maize breeders was used (0 = no symptoms, 5 = severe) such that plants with symptom scores >3 are considered susceptible and would be rejected by plant breeders. At harvest, ten cobs were selected visually as being large size with large, white, evenly spaced seeds, and ten were selected visually as having cobs of average size, large, white, evenly spaced seeds. The seed was removed from each selected cob and the seeds from each batch of ten cobs were mixed together. The seed was then removed from all remaining cobs, bulked and mixed together, and a batch similar to that obtained from each of the previous two batches of ten cobs was retained.

In order to examine relationships between cob or seed size and severity of MSVD, seed from each of the three seed batches was planted in plots at NAARI during the following rains in a randomised block design replicated five times. Each plot comprised 10 seeds planted in a single row at 0.3m spacing. Each plant was inoculated with MSV by caging on an upper leaf for 2 days, three laboratory-reared *Cicadulina mbila* (Naudé) that had been kept for 2 days on an MSVD-affected maize plant. Plants were then scored for severity of symptoms on several subsequent dates over the growing season.

The results showed that about 10% of the Longe 1 plants grown at Sendusu farm were affected by MSVD, the majority developing quite severe (categories 4 & 5) symptoms (Table 11). Plants with mild to moderate symptoms (categories 1-3) yielded less, but not significantly so (P>0.05), than 100 randomly selected symptomless plants whereas the more severely diseased plants yielded 40-60% less (P<0.001). However, despite the high proportion rated category 5, few plants exhibited extremely severe symptoms in which new foliage is completely bleached leading even to plant death.

Severity	0 (Symptomless)	1	2	3	4	5
Number of plants	100	39	72	99	83	206
Average yield	101.4	89.8	93.4	91.0	61.4	47.0
St. Dev	46.3	61.4	55.7	54.6	46.9	47.6
S.E.	4.7	9.8	6.6	5.5	5.1	3.3

Table 11. The average yield (gms dried seed) of maize plants cv Longe 1 affected by MSVD and a random selection of 100 symptomless plants from the same plot.

Seed samples (100 seeds) taken from large cobs with large seeds weighed 34.6 ± 0.58 g, seed samples from cobs with large seeds weighed 34.2 ± 0.42 g whereas seed samples taken from the bulk sample weighed only 28.6 ± 0.46g. Most plants grown from all batches of seeds were successfully inoculated with MSV. More plants grown from the seeds from large cobs with large seeds or cobs with large seeds had severe symptoms than plants grown from the bulk batch although this was not statistically significant (Table 12).

Severity		1	2	3	4	5	% 4 & 5	*Probability*
29 May	A	0	1	7	10	4	64	
	B	0	1	8	12	6	67	NS
	C	1	2	8	14	9	68	NS
12 June	A	0	0	4	10	5	79	
	B	0	0	1	12	13	96	NS
	C	0	0	3	6	27	91	NS
1 July	A	0	2	8	9	3	55	
	B	0	1	10	13	4	61	NS
	C	0	1	7	15	10	76	NS
7 July	A	0	1	9	10	2	55	
	B	0	0	8	15	4	70	NS
	C	0	0	7	16	10	78	NS

Table 12. Experiment 1: severity scores at four different dates of inoculated maize seedlings grown using seed batches from (A) bulked cobs, (B) large cobs with large seeds, (C) cobs with large seeds. Probability of the percentage plants in the severe categories 4 and 5 are calculated against batch A using Chi-squared; NS = not significant (P>0.05).

Cross-pollination by a local variety. Kawanda is a large-seeded, MSV susceptible variety which was released many years ago in Uganda and most closely resembles the local varieties found in Uganda. Longe 1 is smaller-seeded. Forty cobs of Kawanda (MSV susceptible) were hand-pollinated with Kawanda pollen, 40 cobs of Longe 1 (MSV resistant) were hand-pollinated with Longe 1 pollen and 40 cobs of Longe 1 were hand-pollinated with Kawanda pollen. The weights of each seed in a random sample of 100 seeds taken from each treatment were measured to examine the effect of pollen source on the size of seed. The results confirmed that Longe 1 seeds are smaller than Kawanda seeds but also showed that Longe 1 cobs pollinated by Kawanda pollen produced seed that was larger (Table 13).

Cross	No. cobs	Mean cob wht gms	Mean No. seeds per cob	Mean wht of seeds	Wht per 100 seeds from mid cob
LxL	40	136.2	291.2	107.8	39.7
KxK	40	145.5	292.1	118.7	43.2
LxK	34	157.7	314.6	127.2	42.5

Table 13 Size of seed, based on the mean for 100 seeds, resulting from Longe x Longe (LxL), Kawanda x Kawanda(KxK) and Longe X Kawanda (LxK) crosses.

In the next season, seed was selected from each cross based on large or medium sized, well-filled, cobs with large or small seeds. Seeds from these were then planted at NAARI during the second rains of 1998 using a similar experimental design and planting distances as before to examine relationships between seed size and severity of MSVD. Plants were inoculated with MSV using viruliferous *C. mbila* as before and plants scored for severity of symptoms on two dates over the growing season. The results (Table 14) show that symptoms were less severe on plants from the Longe x Longe crosses than the Longe x Kawanda crosses and these were less than the Kawanda x Kawanda crosses. Overall, these results suggests that farmers selecting for large-seeded cobs amongst Longe 1 are likely to select ones that have been pollinated by a large-seeded variety such as Kawanda or similar local variety and that the susceptibility of the latter to MSVD will be evident in the subsequent crop.

TREATMENT	LxL(L)	LxL(S)	KxK(L)	KxK(S)	LxK(L)	LxK(S)
No PLANTS	50	47	48	49	49	47
No INFECTED	26.0	31.0	38.0	43.0	43.0	35.0
% INFECTED	52.0	66.0	79.2	87.8	87.8	74.5
MEAN SYMPTOMS	2.5	2.7	3.3	3.2	2.8	2.8
ST DEV	1.0	1.3	1.3	1.3	1.3	1.4

Table 14 Mean MSVD symptom score observed at the last reading on plants derived from seed from different crosses. L = Longe 1, K= Kawanda, (L) = large seed, (S) = small seed.

Seed selection within a Longe x Kawanda cross. In a first experiment, seeds were collected from naturally infected plants showing severe symptoms (rated 4-5) and mild symptoms (rated 1-2). The idea of this was to examine whether plants from parents with mild or severe symptoms would produce progenies with similarly mild or severe symptoms in the next generation and also to examine if there was any relationship between seed size and disease expression. The results showed that there was little difference between the size of seed produced by the two treatments. However, plants derived from severely infected parents showed much less resistance (based on symptoms expressed) than those from mild symptom parents (Table 15). This shows that it is relatively easy to select back MSVD-resistance by selecting seed from plants with mild symptom expression.

	27/11/98			18/12/98		
Treatment	N	% INFECTED	Mean S	N	% INFECTED	Mean S
Seeds from severely streaked plants (4-5)	82	17.86	3.4	82	27.58	3.65
Seeds from mildly streaked plants (1-2)	91	13.63	2.25	91	18.08	3.19

Table 15 The mean symptoms (based on a rating of 1-5) of plants derived from severely streaked parents (rated 4-5) and derived from mildly streaked plants (rated 1-2) at two readings during growth.

In a second experiment, cobs were collected from plants from the Longe x Kawanda crosses and the cobs were categorised according to size into ones with large, medium or small seeds based on the weight of 100 seeds. Seed from 10 cobs with the largest seeds, smallest seeds and median seeds were bulked and samples were sown in the field in a randomised block experimental design. Plants were inoculated with MSV using viruliferous *C. mbila* and plants scored for severity of symptoms on two dates over the growing season. The results are shown in Table 16 for the two reading dates. Once again there was a tendency for plants derived from small seeds to be the most resistant.

	27/11/98			18/12/98		
Treatment	N	% INFECTED	Mean S	N	% INFECTED	Mean S
Large seeds	41	76.70	3.68	41	84.25	4.12
Small seeds	42	87.43	3.32	41	86.00	3.92
Medium seeds	47	92.00	3.56	47	92.00	4.14

Table 16 The mean severity of MSVD (rated between 1 and 5) of plants artificially inoculated in the field that have derived from parents of Longe x Kawanda crosses with large, medium or small seeds.

Conclusions on the effects on MSVD-resistance in Longe 1 of traditional farmer selection. The Ugandan farmers interviewed made no mention of preventing cross-pollination between their landraces using either spatial separation or temporal separation through the different times of flowering of landraces: *c.* 200 m is required to isolate one maize cultivar from another (Villena, personal communication in Bellon & Brush, 1994). The farmers' traditional system of selecting their seed for the next growing season largely involved no selection in the growing crop and so allowed no direct selection for MSVD-resistance. Seed selection was done largely at the homestead by examining whole cobs and selecting for large, well-filled cobs with large, white seeds. Our results suggest several ways in which this set of circumstances could generate resistance breakdown in Longe 1:

1. Longe 1 cobs cross-pollinated by local large-seeded varieties had larger seeds than Longe 1 cobs pollinated by Longe 1 pollen (Table 13). In a crop of Longe 1, it therefore seems likely the farmer will preferentially select any Longe 1 cobs in which a large proportion of the seed have been pollinated by nearby local crops. Seedlings from these cobs are more MSVD-susceptible than the parent Longe 1 (Table 14).

2. Plants growing around the edge of a crop are likely to suffer less competition for light, water and soil nutrients than plants in the centre of a crop. Cobs of plants growing around the edge are therefore likely to be larger and better filled than cobs on plants in the centre, and therefore selected for seed. However, edge plants are also the most likely to be cross-pollinated by neighbouring local varieties. Consequently, selection for large, well-filled cobs is again likely to select ones cross-pollinated by the local susceptible variety and again seedlings from these cobs will be more MSVD-susceptible than the parent Longe 1 (Table 14).

3. Within a variety or seed batch, there seemed to be a trend for the large-seeded seeds preferentially selected by the farmers to produce plants which are more susceptible to MSVD than plants produced from small-seeded seeds (Tables 12 & 16). Similarly, Parnell & McDonald (1943) and McDonald, Ruston & King (1944) found that MSVD-resistant maize lines synthesised from crosses between resistant and susceptible cultivars yielded less when uninfected than the susceptible parents. Yield of 20 South African maize hybrids was also positively correlated to their yield loss when affected by MSVD ($P<0.05\%$: analysis of data in Table 12, Barrow, 1992), resistant and highly resistant hybrids yielding on average 13% less than susceptible ones when uninfected with MSV. This is consistent with pest resistance often involving some cost (Van Emden, 1991; Harlan, 1992; Crute, 1998).

4. The selection of a few whole cobs by farmers rather than a sample of seeds obtained from a large number of cobs will magnify any of the above effects.

5. The selection of just a few cobs means that, except in extreme epidemic years, these are all likely to derive from plants which escape infection, as even mildly diseased Longe 1 plants seemed to yield slightly less than uninfected ones (Table 11). This would allow no selective advantage for MSVD-resistant genotypes.

6. The farmer's concept of MSVD being soil-derived might not readily suggest the feasibility of selecting tolerant genotypes.

The village survey work showed that most farmer groups grew only one or, at most two, local landraces of maize (excluding popcorn). In Mexico, where the crop has long been domesticated, traditional farmers may each cultivate three or more local cultivars, with perhaps 15 cultivars grown throughout a community (Bellon & Brush, 1994; Louette, Charrier & Berthaud, 1997). This may be because maize is a relatively recent crop in Africa and reflect the need for time to gain specialist knowledge in controlling variation in a cross-pollinating species. As in Uganda, seed selection based on visual characteristics of de-husked cobs is the main means by which American smallholders traditionally maintain their diverse landraces: (Bellon & Brush, 1994). Selection is also done around the homestead separate from the crop itself by American smallholders (Johannessen, 1982; Belloni & Brush, 1994; Louette *et al.*, 1997) as we also observed in Uganda, suggesting that this is appropriate for the crop.

Although this study has identified several ways in which MSVD resistance may have little or no selective advantage within the traditional Ugandan system of selecting seeds, this in no way implies that resistance is not a worthwhile character - since MSVD is devastating to current susceptible landraces. What this study has done is to identify weaknesses in the traditional system which need to be tackled by giving farmers a correct picture of what causes MSVD, how it spreads, knowledge of resistance to MSVD, how it can be selected for and the importance of avoiding cross-pollination by local susceptible landraces.

1.3 *Access to maize seed in Iganga District: towards empowering farmers*

Background

Access to appropriate good quality maize seed was identified as an issue by farmers in:

a) the Situation Analysis of Maize Growers carried out in four villages in Tororo and Iganga districts in October/ November 1996,and in the

b) follow-up activities in participating villages.

On the basis of the above, the project carried-out various activities relating to seed, particularly Longe1.

Seed types, sources and availability in Iganga District

- In Iganga, and particularly some counties of the district, maize is a very important crop.
- In Mamukubembe and Bugodi it is ranked second in importance for both food and cash.
- Iganga district produces *c.* 10% of national maize output.

Two varieties (both open-pollinated) have been released in Uganda which are recommended for agro-ecological conditions such as those found in Iganga. These are Kawanda Composite A (released in 1971) and Longe1 (released in 1991).

Situation at the District Level

There are a number of organisations / programmes involved in the supply of maize seed in Iganga district.

Sasakawa Global 2000

- Overall aim of improving food security.
- Operating in Iganga since February 1997 with an anticipated life of five years. Operates mainly through the district extension service.
- Facilitating the purchase of Longe1 seed from private seed companies and the national seed project by a private company, which is then sold through retail outlets.

IDEA (Investment in Developing Export Agriculture)

- USAID-funded programme aiming to increase the incomes of rural producers from selected non-traditional low-value and high-value export crops.
- The five year programme in Iganga started in 1995 and is being co-ordinated and implemented at district level by the extension service. In Iganga beans and maize are being promoted. Two of the main elements of the programme are input supply and marketing.
- Input supply is essentially concerned with seed and fertilisers. IDEA facilitates the provision of seed through the private sector. This involves a wholesaler and a network of stockists identified and trained under the UJIMA programme. Each stockist should have established a demonstration plot in 1998.

- Marketing - the UJIMA stockists are also being encouraged to provide a market for maize. In collaboration with the Multipurpose Training and Employment Association (MTEA) IDEA are providing credit for the purchase of maize. The scheme, which started in 1997, is administered by the MTEA.

Sukura Agro Supplies Ltd

- Sukura is a private company involved in the supply of agricultural inputs.
- Both the SG2000 and IDEA programmes are working with this company to promote Longe1.

FOSEM (Food Security and Marketing for Smallholder Farmers)

- The On-Farm Productivity Enhancement Programme (OFPEP) was a 5 year

USAID-funded programme which ended in September 1997. It's successor is FOSEM.

- In 1995/96 OFPEP reported 388 tonnes of Longe1 seed were planted as a result of the programme's activities. Under OFPEP farmers in three districts, including Iganga, were trained in seed production techniques.
- Unfortunately, no maize seed was produced in Iganga under this programme. However, farmers have produced seed in neighbouring Mukona district and Busia district on the Kenyan border. In the 1998a season the Busia group sold two tonnes of seed to farmers in Iganga.

Situation in Mamukubembe and Bugodi villages

Information has been collected from farmers on the maize seed which they had planted in 1997a, 1997b, 1998a and 1998b.

The sample from each village, Mamukubembe (36 farmers) and Bugodi (24 farmers) was not random, but consisted of farmers who had been involved in the earlier project's MSVD monitoring activities. Their perceptions and experiences serve to show the trends over a period of time, indicate the likely range of sources of maize seed and farmers' ideas on why changes in the agricultural system have occurred.

Seed type: Local v Longe1

During group discussions in 1996 (Situation Analysis) two main seed types were reported to be grown in Mamukubembe and Bugodi, 'local' and Longe1. In Mamukubembe some farmers obtained Longe1 from neighbours, but most used local and almost all used their own seed. In Bugodi, farmers estimated that about 60% plant local and the rest Longe1. However, it appeared that their Longe1 seed may have been re-cycled many times.

In both villages there appears to have been a decline in the proportion of farmers planting local and an increase in those growing Longe1 between 1997a and 1998b (Fig 1).

Diverse reasons were given by individuals for growing Longe1, but the most consistent explanation appears to be it's early maturity and to a much lesser extent it's greater yield

In both villages, the sole planting of local maize declined throughout the first three seasons (and into 1998b in Bugodi) and in both villages there has been a shift towards growing both local and Longe1 (Fig 2).

The explanations given revolved around:

- Poor performance of Longe1 in the 1997b season (an exceptionally wet season linked to El Nino)
- A wish to spread risk, and the harvesting and weeding periods through diversity
- Lack of access to seed (no home seed or lack of money).

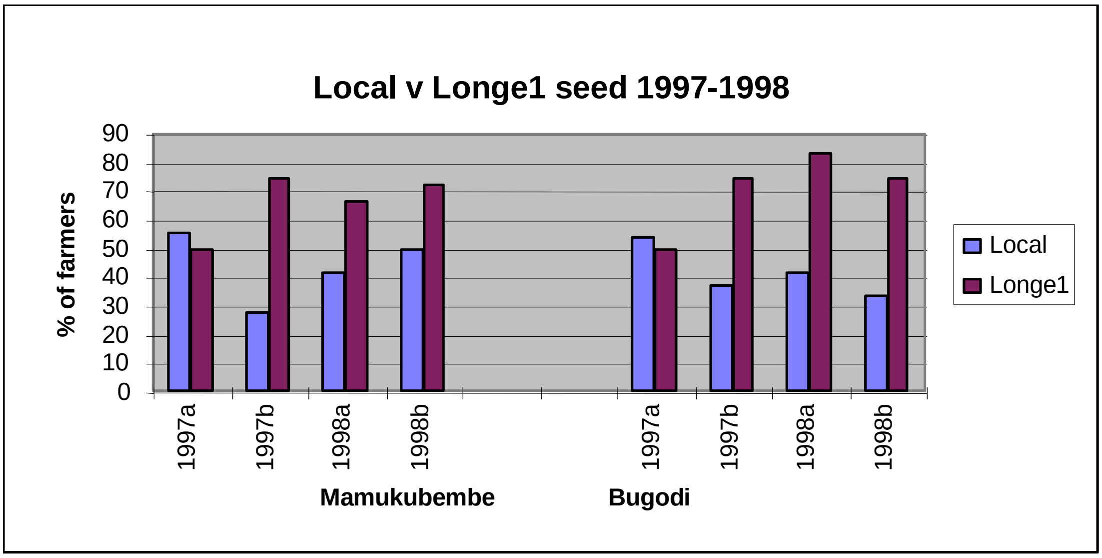

Fig 1 The percentage of farmers growing Longe1 and local varieties over two years

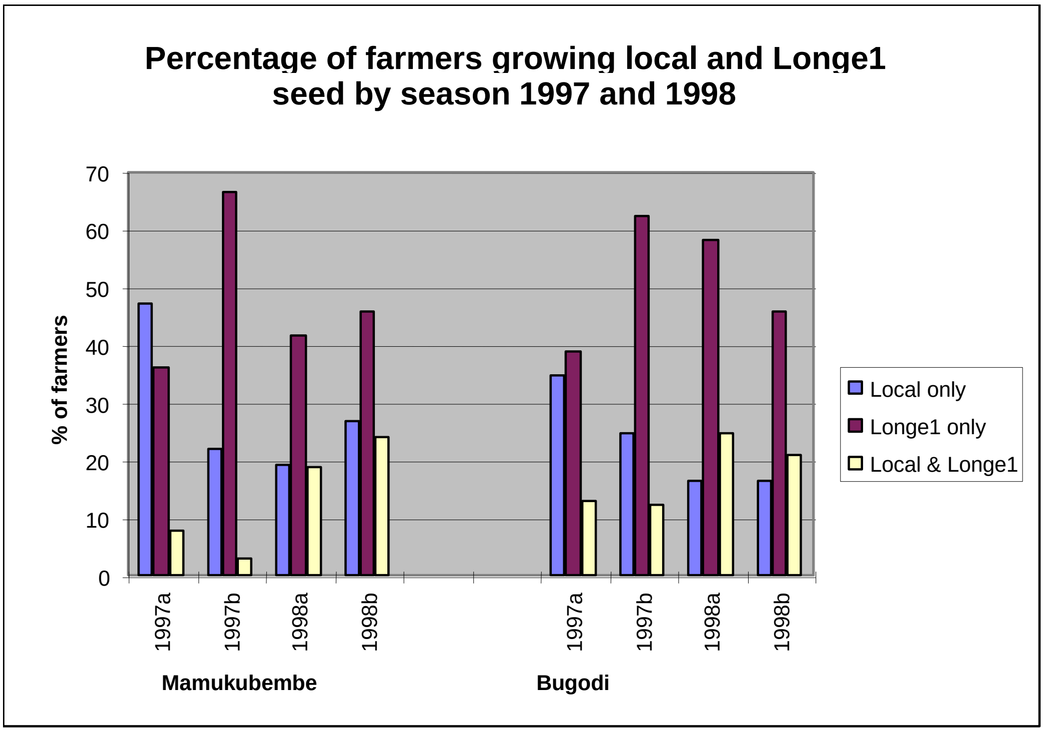

Fig 2 The percentage of farmers growing Longe1 and local varieties or both varieties over two years

'Original' Longe1 v 'Re-cycled' Longe1
Mamukubembe. A high proportion of farmers are growing Longe1 (Fig 2), but the proportion of re-cycled Longe1 is increasing (Fig 3).

Bugodi. An even higher proportion of farmers are growing Longe1 and the trend is upwards (Fig 2), but a very high proportion of the Longe1 seed is re-cycled (Fig 3).

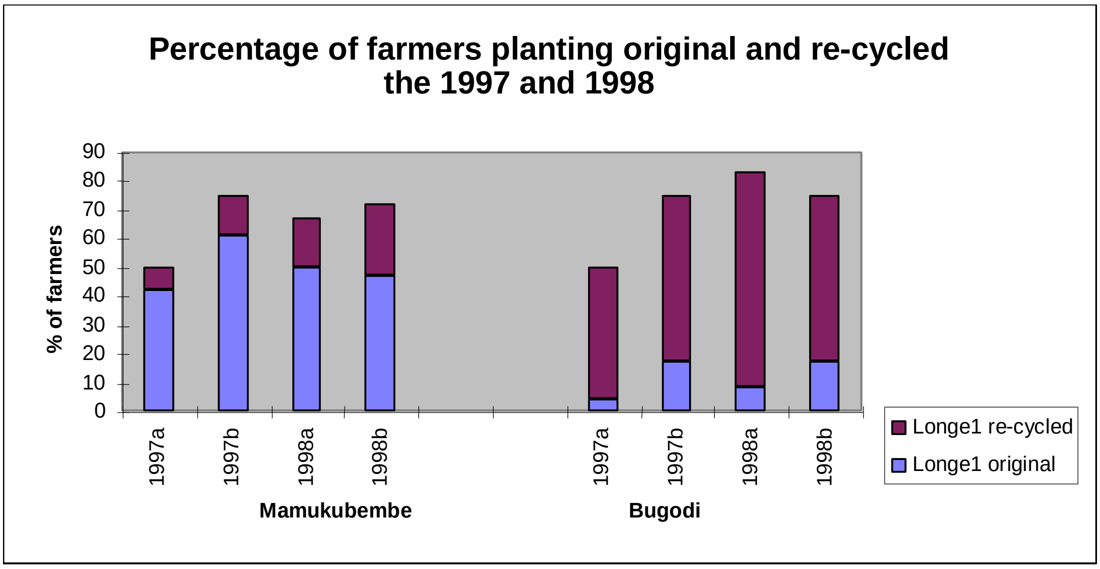

Fig 3 The percentage of farmers planting original and recycled Longe1 over two years

Source of maize seed

There was a big difference between the source of Longe1 seed in Mamukubembe and Bugodi (Table 17).

Mamukubembe					Bugodi				
	1997a	1997b	1998a	1998b		1997a	1997b	1998a	1998b
SG2000	16	12	8	10	District Ext.	0	17	5	0
Ujima	58	69	50	35	Demonstrations	46	28	30	0
Shop	0	4	8	10	Shop	0	0	10	22
Friends/ relatives	16	4	13	3	Friends/ relatives	8	22	15	11
Own	5	12	13	28	Own	23	17	20	39
FAO	0	0	8	0	St Ngondwe/ Byekwaso	15	17	20	28
Other	5	0	0	14	UNAFA	8	0	0	0

Table 17 Sources of Longe1 seed (original and recycled) by season (percentage of responses from farmers growing Longe1)

In Mamukubembe there is a Ujima stockist and within this sample at least half of the farmers planting Longe1 obtained their Longe1 seed from this source over the last three seasons. The decrease between 1997b and 1998a is consistent with the reported sales declining from 200 kg in 1997b to 150 kg in 1998a. Other sources of original seed were given as SG2000 (there is a group in the village) and shops outside the village. The extension service distributed what was described by farmers as 'FAO seed' free as famine relief. This seed is reported to have had very low rates of germination.

The sample of farmers in Bugodi make much more use of re-cycled Longe1 than in

Mamukubembe. St Ngondwe farmers group has been active in setting-up Longe1 demonstrations/seed multiplication plots (with seed from the district extension service). The seed harvested from the demonstrations is provided free to members of the group and at a cost of Ush 500/ kg to non-members.

Seed production by farmers

This project has focused on methods of reducing the impact of MSVD based on knowledge of vector behaviour and farmers practices. On-farm, monitoring has helped to improve researcher understanding of influences on MSVD incidence and severity. It has also given a better appreciation of the scope for farmers to respond to MSVD management options. Participating farmers have improved their understanding of MSVD.

One of the key issues that has emerged is that of the availability of seed. In particular the lack of good quality maize seed (identified by farmers themselves), and farmer selection of seed (identified by researchers).

Plants from seed that were purchased as Longe1 have been observed in the field with severe MSVD symptoms although they should have been showing a reasonable level of resistance.

There is some indication that the method of seed selection carried out by farmers identified during the Situation Analysis (i.e. selecting large seeds) and selecting out MSVD resistance (see below).

Within the area of seed and its selection there are clearly those aspects where farmers are very knowledgeable and those where they are not. For example, farmers appear to be very knowledgeable and aware of maturity periods, yield and possibly response to weather conditions, but are less knowledgeable about, for example, the influence of seed selection procedure on subsequent crops and how pollination occurs.

The issues of seed availability, farmer seed selection and farmer knowledge are all linked and many farmers are unable to buy seed. Those farmers who can afford to buy seed have experienced problems with the seed they have purchased. Improving farmers knowledge of the biology/breeding of maize will enhance their ability to produce better seed.

FOSEM have encouraged farmer production of a range of seeds, including maize (but not in Iganga). CIAT have instigated and monitored farmer bean seed production in Iganga and Mbale districts.

Most maize growers are, in effect, already producing their own seed. In Bugodi the St Ngondwe group was bulking up Longe1 1, although under what conditions (i.e. isolation) was unclear. In Mamukubembe there is enthusiasm for improved access to good quality seed. This encouraged researchers to explore the options for enabling farmers to produce good quality maize seed.

1.4 *Assessment of farmers' ability to maintain improved varieties of maize*

In response to farmers' concern of obtaining and sustaining good maize seed, four representative farmers from each monitoring village were brought to NAARI to see the work of the Cereals Programme, in particular the breeding techniques and demonstrations of the loss of resistance due to cross pollination. The farmers were given practical experience in pollination techniques in order to keep the good qualities of Longe1, in particular maize streak resistance. They were then provided with good quality Longe1 seed which they subsequently planted in their own farms.

In Mamukubembe each of the four farmers who had been trained at Namulonge planted Longe1 seed separately on their own land. In Bugodi all the seed was planted on one plot under the auspices of St Ngondwe farmers group. As in previous seasons, Mamukubembe was ahead of Bugodi in terms of planting time. In both villages, Moses Obellu (Cereals Programme technician) and staff of the MSVD project carried out demonstrations of pollination and, by practical demonstration over a number of days, more than 30 farmers were taught how to carry out pollination using bags to protect the plant from being fertilised by other pollen. The farmers have been very enthusiastic about taking up this technique. Several hundred cobs were available for seed the next season.

An evaluation of the seed work was carried out in Mamukubembe. As well as about 40 farmers, Dr Joseph Kikafunda (Cereals programme agronomist), Solomon Kaboyo and James Kayongo (Cereals technicians), Ezra Okoth (FOSEM), Alphine Karimarimo (IDEA), James Bakaikwira (Extension service) participated. The four farmers who had visited Namulonge and received seed were asked to explain what had happened after the visit, who was involved and why activities had been carried out. They were then asked to list the things that were good and not so good about the process. Possible next steps were then discussed. The four farmers who produced the seed were planning to sell it to other farmers. A similar exercise with the same evaluating group was carried out in Bugodi. The different techniques for isolation of Longe1 plants from cross-pollination were discussed with the groups and the results are shown on Table 18.

Technique	Mamukubembe	Bugodi
Planting Longe1 seed 2 weeks earlier than local seed	Problem with rainfall Children are available at earlier stage May work if dry planting	May miss the first rains. Earlier planted maize attracts thieves and monkeys
Planting Longe1 seed in isolation from other maize (400m?)	Not enough land in the village	Impossible due to land shortage
Planting only Longe1 in a given locality	All farmers in area will have to agree	May be possible, but doubts about all farmers agreeing and implementing
Buying Longe1 seed every season	Costly	Costly and it is felt that Longe1 seed can be re-cycled for 2-3 seasons
Pollination method	Labour intensive and needs bags	Needs paper bags and pins

Table 18. Farmer evaluation of techniques for producing seed after one season

In Mamukubembe the farmers who produced the seed planned to keep some and sell some to other farmers. There were plans to produce seed next season using improvised pollination bags.

In Bugodi the St Ngondwe group planned to share seed within the group and sell to non-members.

Both groups were enthusiastic about continuing and expanding their maize seed production activities.

2. *Disease and vector monitoring*

2.1 *Monitoring under controlled conditions*

Progress of epidemics of maize streak disease in 14 of the monitoring plots consisting of 40x60 maize stands was analysed and related to vector catches on sticky pole traps in these plots. In 13 plots a logistic curve was a good fit. In each case the three parameters of the logistic curve (*a* = upper asymptote of streak incidence; *b* = rate of progress (day^{-1}); *m* = time of the inflexion point of the disease progress curve) were estimated. Parameters of the logistic curve were correlated with each other. Plots with a high initial rate of increase also had an earlier inflexion point and a high asymptote (see Fig 4). Correlation coefficients were r_{bm}=-0.637, r_{ba}=0.664, r_{ma}=-0.472. For 11d.f. (In all cases the correlation coefficient was calculated on 13 plots) values of r significant at p=0.05 were 0.553.

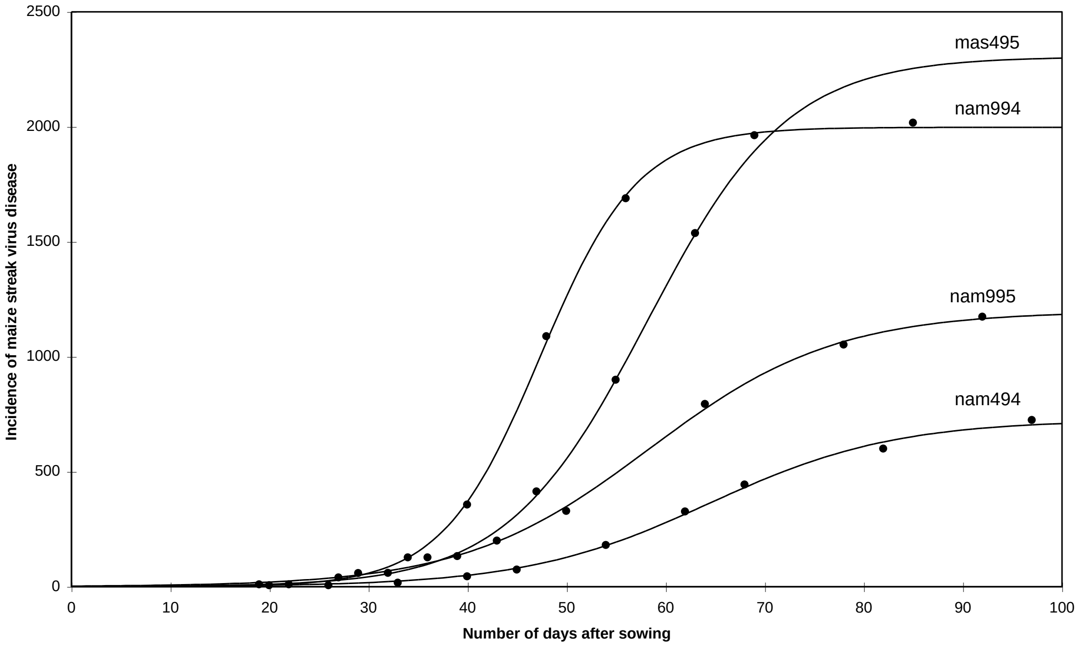

Fig 4. Number of stands displaying symptoms of MSVD against number of days after sowing the maize crop for four plots. Observed data (●), and fitted logistic curves are shown.

To explore further any relationships between the shape of the disease progress curve and vector catches a multiple linear regression model was then fitted to *b*, *m*, or *a* using a stepwise procedure. Six explanatory variables were included in the model: cumulative catch of male *C. mbila* up to 14 d.a.s.(days after sowing) (M1), from 15-28 d.a.s. (M2), and 29-56 d.a.s (M3); cumulative catch of female *C. mbila* up to 14 d.a.s.(FM1), from 15-18 d.a.s.(FM2), and 29-56 d.a.s (FM3). For all three dependant parameters the best model had only a single explanatory variable which was the cumulative catch of either male or female *C. mbila* to 14 d.a.s. (Table 19 and Fig 5). No relationship was found between disease progress and vector catches later in the epidemic, or with the catches of the other vector species *C. storeyi*.

These results are of interest because they suggest that disease progress is determined by conditions which are present in the crop at an early stage in the epidemic. Thus plots which were characterised by a high initial rate of increase were those in which final incidence was also high. In addition there are correlations between parameters describing disease progress and catches of *C. mbila* at a very early stage. However disease progress data indicate that there were very few infections before 20 d.a.s., and since the time from infection to symptom appearance is only 3-7 days in young plants (Gibson and Page, 1997) it is unlikely that vectors caught up to 14 d.a.s. caused many infections in the crop. One explanation is that early vector catches are indicative of numbers of viruliferous vectors in the crop at a later stage. Tests have shown that *C. storeyi* is a less efficient vector of streak than *C. mbila* (see below), and this would explain why *C. storeyi* catches were not well correlated with disease progress. In addition numbers at the beginning of the season may be more indicative of the true population of *Cicadulina* present in the field and wild grasses, higher numbers in a plot being more likely to attract other individuals in (see attraction work part 2.6).

Linear regression fitted to *b* (rate of disease progress)

Variable	Estimate	s.e.	t	sig t
M1	0.00131	0.00036	3.66	0.0033
Constant	0.08287	0.01301	6.36	0.0000

Linear regression fitted to *m* (inflexion point)

Variable	Estimate	s.e.	t	sig t
FM1	-1.282	0.582	-2.204	0.0497
Constant	63.01	3.33	18.9	0.0000

Linear regression fitted to *a* (asymptotic disease incidence)

Variable	Estimate	s.e.	t	sig t
M1	17.11	6.42	2.66	0.0219
Constant	580.6	231.9	2.50	0.0293

Table 19 Best fitting linear regression models to parameters describing MSVD progress in plots of maize.

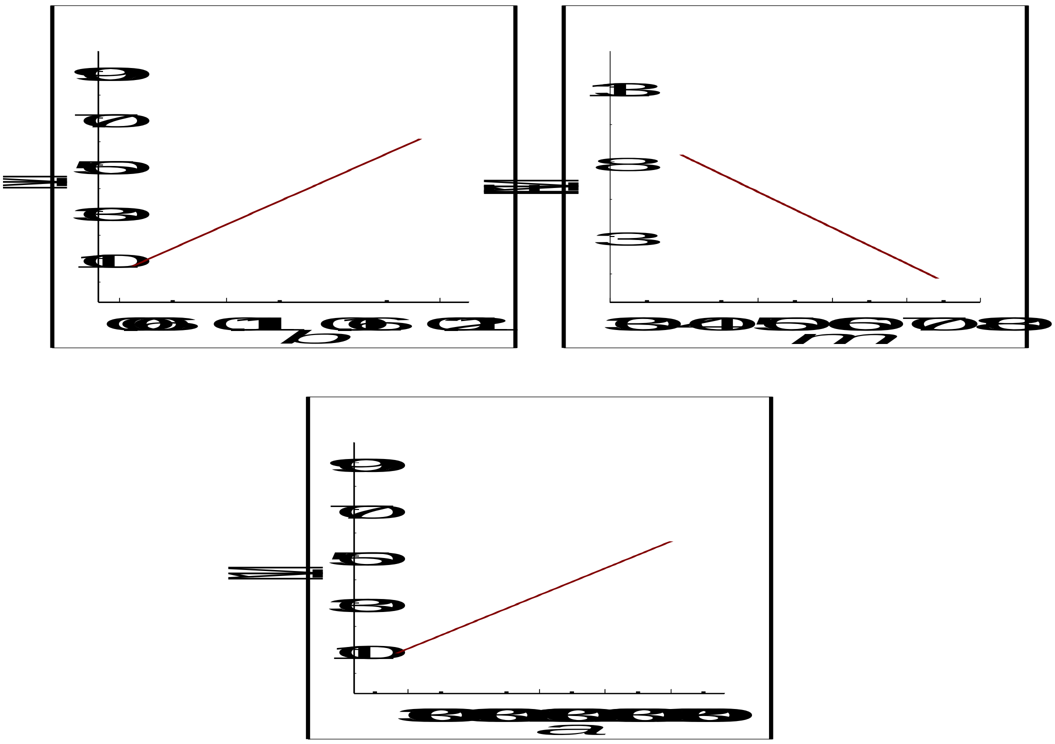

Fig. 5 The best fitting linear regression models to the parameters of the logistic curve fitted to disease progress (equations are given in the preceeding table): Regressions were fitted to *a* (asymptotic disease incidence), *b* (rate of disease progress), *m* (inflexion point). Filled circles represent observed points, straight line is the fitted line.

The spatial distribution of infected stands was also analysed in four of these plots. Two techniques were used to identify clustering of diseased stands: fit to the beta-binomial distribution (Madden and Hughes, 1994), and 2DCLASS analysis (Nelson and Campbell, 1992).

d.a.s.	Parameter estimates P	SE	θ	SE	Goodness of fit beta binomial df	significance of χ^2	binomial df	significance of χ^2
nam394								
45	0.033	0.005	0.073	0.022	1	0.47	1	0.000
54	0.082	0.009	0.089	0.020	3	0.30	3	0.000
62	0.148	0.012	0.085	0.022	6	0.85	4	0.000
68	0.202	0.014	0.095	0.021	8	0.85	5	0.000
82	0.272	0.015	0.085	0.018	8	0.62	6	0.000
97	0.328	0.016	0.088	0.018	9	0.67	6	0.000

Table 20 Epidemic development in plot nam394. Parameter estimates and goodness of fit for beta-binomial (aggregated) and binomial (random) distributions fitted to incidence counts from contiguous 5x5 quadrats.

Diseased stands were found to be highly clumped (Table 20) but new foci were generated throughout the season. These findings were thought to be related to the mating behaviour of the vector where male vectors find stationary females which are themselves thought to prefer maize plants of a favoured height, the distribution of which changes over the season. This could in itself produce the pattern of aggregation seen here. The epidemic, over time, fits a logistic curve characteristic of a compound interest disease in which there is secondary spread. The spatial pattern, however, suggests that secondary spread is not very important because the foci do not increase in size very much in most cases (example in Figs 6 and 7). Indeed if most individuals which acquire the virus in the field are expected to be very active within the field (males) or move out again (females) before they become infective, as is suspected from their use of the crop as a medium for mating rather than a food source, then foci would not be expected to expand.

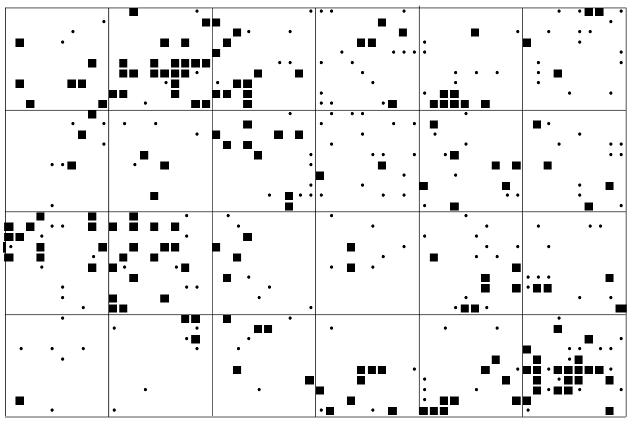

Fig.6 The incidence of streak symptoms in nam394 at 54 d.a.s. Solid squares indicate stands with at least one symptomatic plant, dots indicate empty stands. Disease incidence was 8.1%.

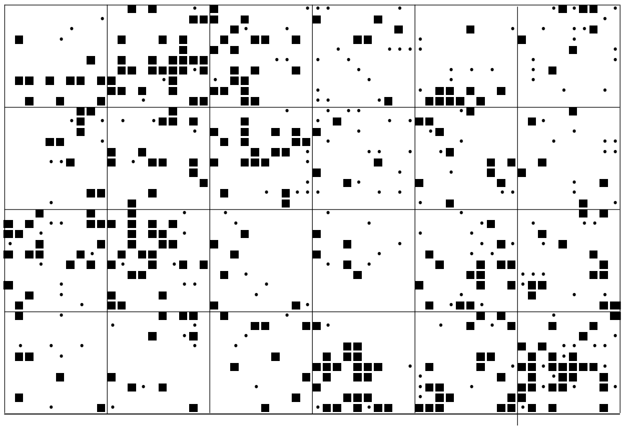

Fig. 7 The incidence of streak symptoms in nam394 at 68 d.a.s. Solid squares indicate stands with at least one symptomatic plant, dots indicate empty stands. Disease incidence was 20.1%.

2.2 *Monitoring of MSV in the selected villages*

In the first season of the study visits were made to all four study village two months after planting to monitor the incidence of MSVD in farmers' fields based on the variety being grown and the pre-selected farm management techniques (i.e. spacing and intercropping). Thirty plots per site were monitored. Because of the considerable variation of the different parameters from field to field it was found that it was not possible to make meaningful comparisons. However there was a strong indication that women's fields had a higher incidence of MSVD that the men's fields (Fig. 8).

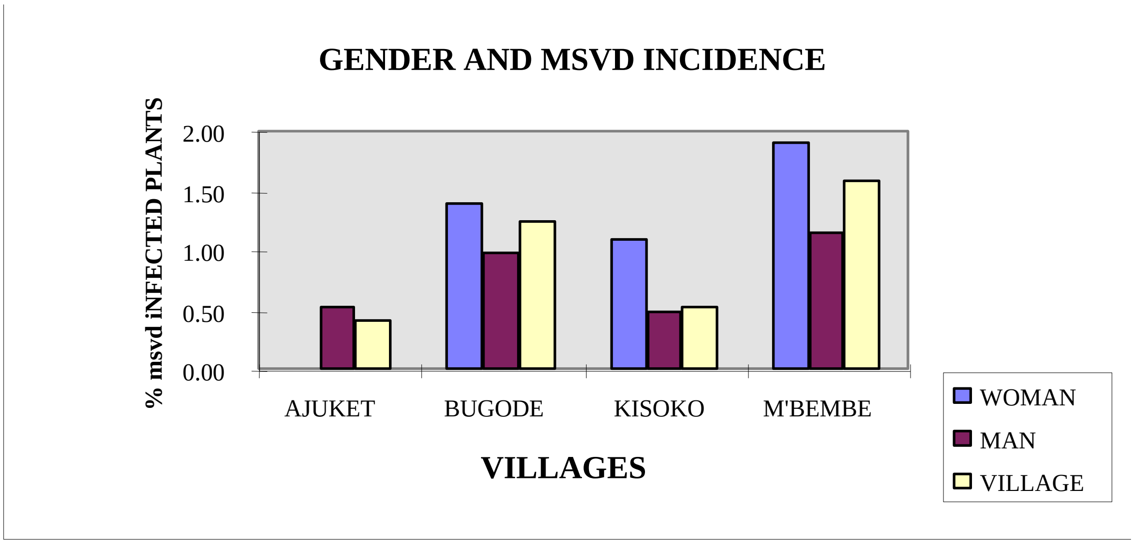

Fig 8 The incidence of MDVD according to the gender of the principal farmer of each field

When the study villages were reduced to two (Mamukubembe and Bugodi), it was possible to monitor MSVD incidence in 60 plots in each village and to gather more detailed information regarding the management of the plots and the varieties being grown. Examples of the information collected over the three seasons:

As in the first season the wide variations in parameters from field to field made the data difficult to analyse (e.g. farmers would increase their maize spacing when intercropping so comparisons with mono-cropped maize were difficult). However the monitoring did produce the following results.

(i) it was found that the incidence of MSVD was much higher in the shade of trees and this was followed up (see below)

(ii) the incidence of MSVD increased in relation to the time of sowing, the later the sowing the greater the incidence (see Figures 9a and b). This confirmed previous on-station work

(iii) the "local" variety of maize appeared to be showing vector resistance. This was subsequently shown to be the case when on-station trials of different varieties of maize were carried out.

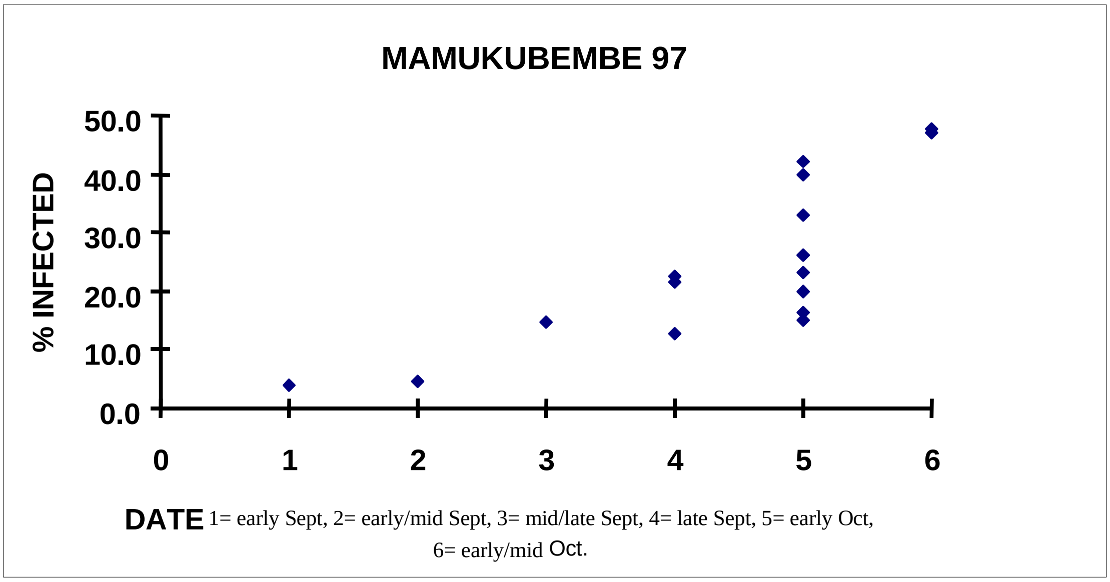

Fig 9a The incidence of MSVD in relation to the time of planting of different maize fields at Mamukubembe

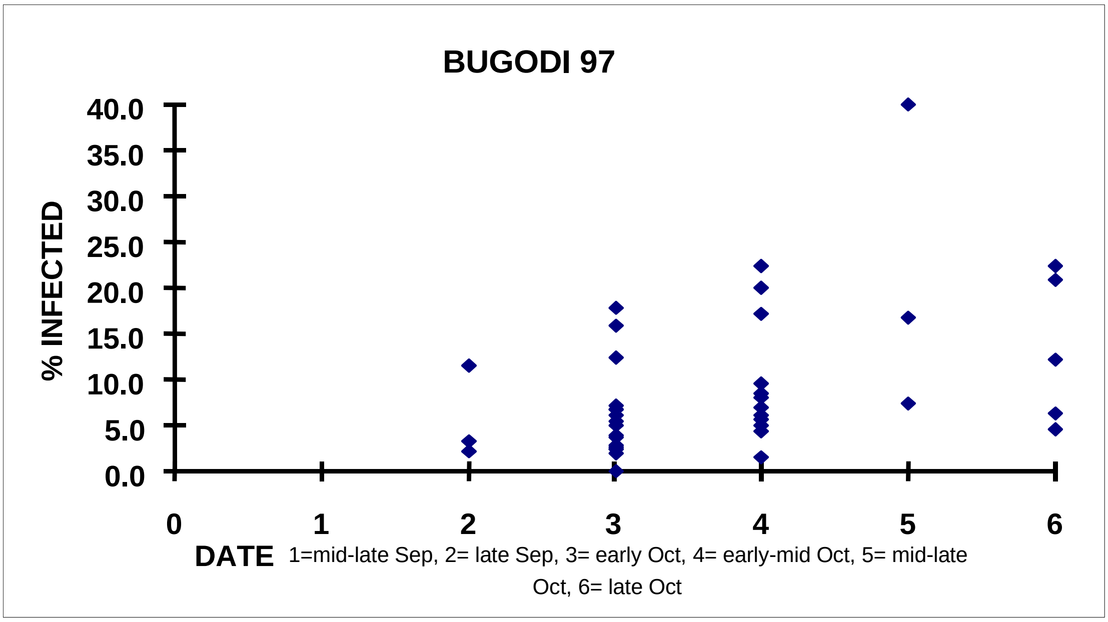

Fig 9b The incidence of MSVD in relation to the time of planting of different maize fields at Bugodi

The above helps to explain why there was an indication that women's fields tended to have a higher incidence of MSVD than the men's in the same village. It was known from the village survey work (see above) that the women would help sow the men's fields first before sowing their own fields. This ensured that they planted later and were therefore more likely to incur a greater incidence of streak.

2.3 *Monitor plants growing naturally with and without shade*

During on-farm studies it was noticed that there were more streaked maize plants under the shade of trees than out of the shade. An extreme example of this (the first plot surveyed) is shown in Figure 10.

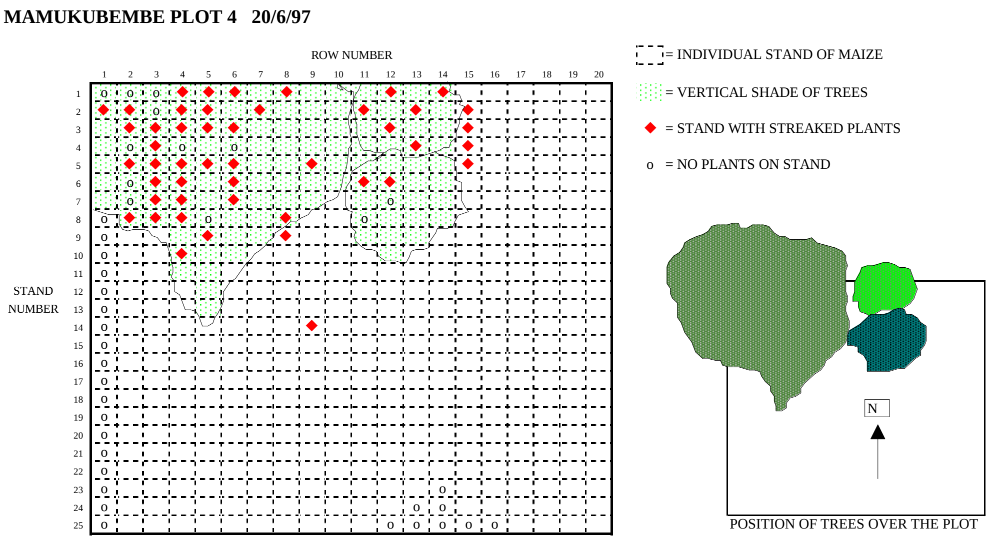

Fig 10 An extreme example of MSVD incidence in the verticle shade compared with maize plants outside the shade.

A survey of 17 plots at two sites showed that 2.9 times more of the plants in the vertical shade had MSVD (Table 21). In addition, by examining the first leaf infected, it was clear that the plants in the shade were, on average, being infected a week or more before those out of the shade (¾ of a leaf difference in development at the time of infection, see Table 21).

	SITE:	M	SITE:	M	SITE:	M	SITE:	M	SITE:	M	SITE:	M
	PLOT No:	40	PLOT No:	15	PLOT No:	A	PLOT No:	30	PLOT No:	25	PLOT No:	1
	No. STANDS IN SHADE	81	No. STANDS IN SHADE	83	No. STANDS IN SHADE	102	No. STANDS IN SHADE	42	No. STANDS IN SHADE	45	No. STANDS IN SHADE	23
	No. STANDS IN OPEN	207	No. STANDS IN OPEN	267	No. STANDS IN OPEN	248	No. STANDS IN OPEN	324	No. STANDS IN OPEN	175	No. STANDS IN OPEN	251
	No. STANDS IN PLOT	288	No. STANDS IN PLOT	350	No. STANDS IN PLOT	350	No. STANDS IN PLOT	366	No. STANDS IN PLOT	220	No. STANDS IN PLOT	274
	PERCENT SHADE	28.13	PERCENT SHADE	23.71	PERCENT SHADE	29.14	PERCENT SHADE	11.48	PERCENT SHADE	20.45	PERCENT SHADE	8.39
	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade
No infected	104	89	71	147	176	235	73	131	76	87	37	83
% infected per stand	128.40	43.00	85.54	55.06	172.55	94.76	173.81	40.43	168.89	49.71	160.87	33.07
% infected per total stands	36.11	30.90	20.29	42.00	50.29	67.14	19.95	35.79	34.55	39.55	13.50	30.29
Mean leaf number	2.49	3.16	2.76	3.95	2.30	3.28	1.77	3.09	1.71	3.20	2.95	3.73
Prop. MSV in shade	2.99		1.55		1.82		4.30		3.40		4.86	
Diff in leaf No.	0.67		1.19		0.98		1.32		1.48		0.79	

	SITE:	M	SITE:	M	SITE:	M	SITE:	M	SITE:	B	SITE:	B
	PLOT No:	2	PLOT No:	B	PLOT No:	58	PLOT No:	C	PLOT No:	C	PLOT No:	34
	No. STANDS IN SHADE	44	No. STANDS IN SHADE	179	No. STANDS IN SHADE	87	No. STANDS IN SHADE	27	No. STANDS IN SHADE	36	No. STANDS IN SHADE	56
	No. STANDS IN OPEN	205	No. STANDS IN OPEN	146	No. STANDS IN OPEN	180	No. STANDS IN OPEN	142	No. STANDS IN OPEN	147	No. STANDS IN OPEN	243
	No. STANDS IN PLOT	249	No. STANDS IN PLOT	325	No. STANDS IN PLOT	267	No. STANDS IN PLOT	169	No. STANDS IN PLOT	183	No. STANDS IN PLOT	299
	PERCENT SHADE	17.67	PERCENT SHADE	55.08	PERCENT SHADE	32.58	PERCENT SHADE	15.98	PERCENT SHADE	19.67	PERCENT SHADE	18.73
	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade
No infected	66	120	70	45	93	92	48	176	24	15	55	57
% infected per stand	150.00	58.54	39.11	30.82	106.90	51.11	177.78	123.94	66.67	10.20	98.21	23.46
% infected per total stands	26.51	48.19	21.54	13.85	34.83	34.46	28.40	104.14	13.11	8.20	18.39	19.06
Mean leaf number	2.39	3.53	3.13	3.07	3.05	3.66	2.35	2.87	4.04	4.13	3.44	4.09
Prop. MSV in shade	2.56		1.27		2.09		1.43		6.53		4.19	
Diff in leaf No.	1.14		-0.06		0.61		0.52		0.09		0.65	

	SITE:	B	SITE:	B	SITE:	B	SITE:	B	SITE:	B
	PLOT No:	D	PLOT No:	30	PLOT No:	E	PLOT No:	F	PLOT No:	A
	No. STANDS IN SHADE	34	No. STANDS IN SHADE	94	No. STANDS IN SHADE	38	No. STANDS IN SHADE	108	No. STANDS IN SHADE	75
	No. STANDS IN OPEN	190	No. STANDS IN OPEN	130	No. STANDS IN OPEN	235	No. STANDS IN OPEN	176	No. STANDS IN OPEN	213
	No. STANDS IN PLOT	224	No. STANDS IN PLOT	224	No. STANDS IN PLOT	273	No. STANDS IN PLOT	284	No. STANDS IN PLOT	288
	PERCENT SHADE	15.18	PERCENT SHADE	41.96	PERCENT SHADE	13.92	PERCENT SHADE	38.03	PERCENT SHADE	26.04
	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade
No infected	23	52	19	21	53	192	62	23	98	96
% infected per stand	67.65	27.37	20.21	16.15	139.47	81.70	57.41	13.07	130.67	45.07
% infected per total stands	10.27	23.21	8.48	9.38	19.41	70.33	21.83	8.10	34.03	33.33
Mean leaf number	1.83	3.00	3.53	3.67	1.77	2.68	3.11	3.17	1.70	2.63
Prop. MSV in shade	2.47		1.25		1.71		4.39		2.90	
Diff in leaf No.	1.17		0.14		0.90		0.06		0.92	

SUMMARY	**No. plots**	**Mean**	**STD**
Proportion MSV in shade	**17**	**2.92**	**1.50 (1.25 TO 6.53)**
Difference in leaf No.	**17**	**0.74**	**0.47 (-0.06 TO 1.48)**

Table 21 The incidence of MSVD from individual plots at two study sites (M = Mamukubembe, B = Bugodi) summarised to show the proportion of streaked plants found in the shade and the age of the plants (as measured by leaf stage)

Two experiments were set-up using artificial shade over four areas (4m^2 and 9m^2 respectively) within a field of maize with four control areas of the same size without shade. Each block had a pole trap in its centre to collect *Cicadulina* on a daily basis. The MSVD incidence in each replicate was recorded on a weekly basis. The results of both experiments are shown in Tables 22 and 23 and can be summarised as follows:

- 93% of all the *Cicadulina* caught were in the shaded areas
- about 84% of all male *C.mbila* were caught in the shade
- about 90% of all male *C.storeyi* were caught out of the shade

- females showed similar trends but at a lower level (60-80%).

This clearly indicates a difference in behaviour between *C.mbila* and *C.storeyi* with regards to shade preference. It also indicates that planting in the shade may have a marked affect on the mate-seeking behaviour of the different *Cicadulina* species and therefore on the incidence of MSVD and subsequent crop loss. It is interesting to note that in the 1998a season *C. bipunctata* followed a similar trend to *mbila* with 95% of the males being found in the shade. This was the only season in five years that *C. bipunctata* was in abundance at Namulonge. The results also suggest why, throughout the regular monitoring of MSVD in plots, *C. storeyi* have been observed to build up in numbers in maize fields at an earlier stage in maize growth than *C. mbila*. The maize at an early stage of growth would not provide the shade preferred by *mbila* but would be relatively open which is preferred by storeyi.

The incidence of streak was also examined during these experiments. However there was no significant difference between the treatments. It is thought that the shade areas were probably not big enough to hold the insects for any length of time on maize plants since the angle of the sun up to mid-morning and mid-afternoon onwards would have ensured that the shade covered areas did in fact have sun on the plants for parts of the day. In addition the nature of the shade (doubled black netting) may not have been entirely suitable.

1997B

MALES	NO SHADE				SHADE				TOTALS		PERCENT IN	
Pole trap number	1	3	6	8	2	4	5	7	NO SHADE	SHADE	NO SHADE	SHADE
Total *mbila*	42	25	31	43	129	157	151	143	141	580	19.6	80.4
Total *storeyi*	11	9	10	11	0	0	0	3	41	3	93.2	6.8

FEMALES	NO SHADE				SHADE				TOTALS		PERCENT IN	
Pole trap number	1	3	6	8	2	4	5	7	NO SHADE	SHADE	NO SHADE	SHADE
Total *mbila*	4	15	6	11	11	17	10	15	36	53	40.4	59.6
Total *storeyi*	3	3	2	3	3	0	1	1	11	5	68.8	31.3

1998A

MALES	NO SHADE				SHADE				TOTALS		PERCENT IN	
Pole trap number	1	3	6	8	2	4	5	7	NO SHADE	SHADE	NO SHADE	SHADE
Total *mbila*	45	41	42	58	380	378	202	341	186	1301	12.5	87.5
Total *storeyi*	9	11	14	27	0	0	0	7	61	7	89.7	10.3
Total *bibunctata*	2	9	4	4	95	118	54	71	19	338	5.3	94.7
Total others	4	6	4	12	0	0	1	1	26	2	92.9	7.1

FEMALES	NO SHADE				SHADE				TOTALS		PERCENT IN	
Pole trap number	1	3	6	8	2	4	5	7	NO SHADE	SHADE	NO SHADE	SHADE
Total *mbila*	3	11	12	9	38	33	30	23	35	124	22.01	77.99
Total *storeyi*	7	7	2	7	4	1	3	2	23	10	69.70	30.30
Total others	1	0	6	2	2	12	4	2	9	20	31.03	68.97

Table 22 The numbers and proportions of *Cicadulina* species found under vertically shaded plots compared with open plots (each plot 4m^2 for 1997b and 9m^2 for 1998a)

	NO SHADE				SHADE			
	mbila	*storeyi*	*mbila*	*storeyi*	*mbila*	*storeyi*	*mbila*	*storeyi*
SEASON	**M**	**M**	**F**	**F**	**M**	**M**	**F**	**F**
1997B	**19.6**	**93.2**	**40.4**	**68.8**	**80.4**	**6.8**	**59.6**	**31.3**
1998A	**12.5**	**89.7**	**22.0**	**69.7**	**87.5**	**10.3**	**78.0**	**30.3**

Table 23 Summary of the numbers and proportions of *Cicadulina* species found under vertically shaded plots compared with open plots (each plot $4m^2$ for 1997b and $9m^2$ for 1998a).

2.4 *Breakdown of resistance if plants are inoculated at a young stage*

Resistance to MSVD in Longe1 has been shown to break down when plants are inoculated young. Seedlings inoculated within a week of germination develop severe symptoms (c. 4 on a 1-5 scale), like similarly inoculated seedlings of a susceptible variety.

2.5 *Determine transmission efficiencies for two vector species*

The proportion of viruliferous male and female *Cicadulina mbila* and *C. storeyi* were assessed in crops of young maize plants (it becomes impractical to capture leafhoppers from full-grown maize) by collecting live specimens using either a D-Vac or sweep-net at NAARI farm. Leafhoppers were caged individually on maize seedlings cv Kawanda Composite A for at least 48hrs after which time they were removed for identification. The plants were sprayed with insecticide and retained in a leafhopper-free screenhouse for at least two weeks so that symptoms of MSV could be expressed (Table 24).

	1995	1996		1997	Total	Transmission
Rains	Second	First	Second	First		%
Species*						
C. mbila (M)	1/33	2/11	4/17	6/52	13/113	11.5
C. mbila (F)	1/50	2/11	7/22	13/63	23/146	15.8
C. storeyi (M)	0/35	0/5	1/16	0/66	1/122	0.8
C. storeyi (F)	1/125	2/17	2/59	0/38	5/239	2.1

Table 24. Transmission of MSV by field specimens of *Cicadulina mbila* and *C. storeyi* without being given additional access to streaked leaves (numerator = transmissions; denominator = number of insects tested). M = Male; F = Female

In the case of first season of 1997 there were sufficient numbers in the weekly samples of *Cicadulina* collected from the field over seven weeks to examine the proportions carrying streak over time. The results show that there is, as expected, a large increase over time in the proportions of *C. mbila* carrying MSV (Fig 11)

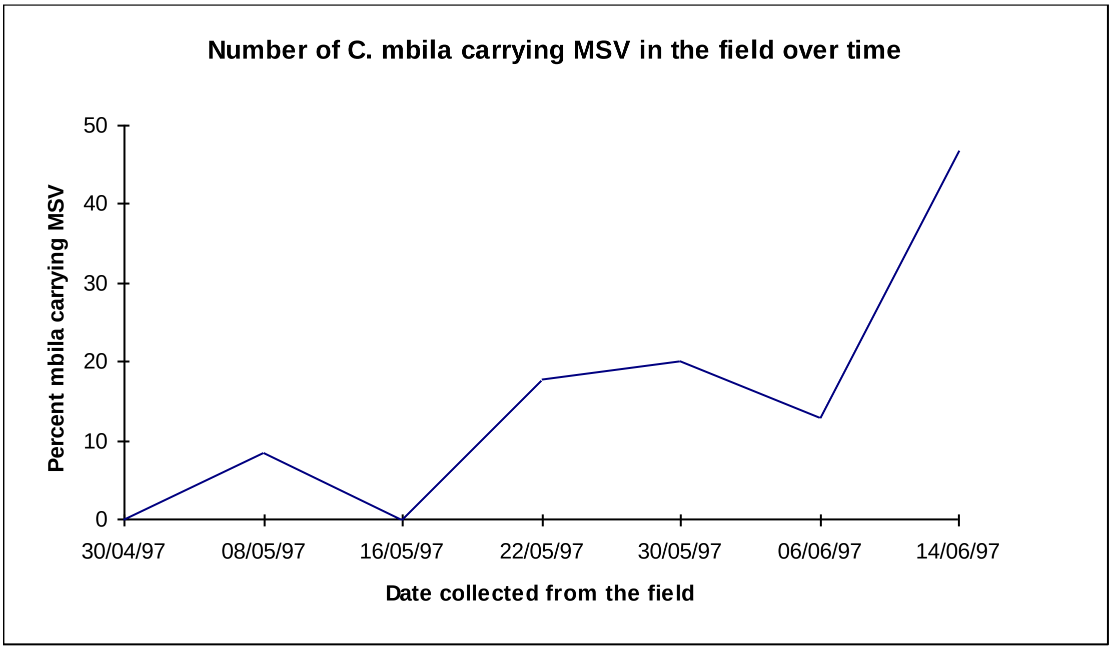

Fig 11 Proportions of *C. mbila* vectoring MSVD in the field over time

Within a *Cicadulina* species known to transmit MSV, not all individuals may be able to transmit MSV. The proportions of so-called "active transmitters" amongst populations of male and female *C. mbila* and *C. storeyi* were assessed in Uganda by allowing adult leafhoppers access to diseased leaves, generally from plants obtained directly from a field or, if unavailable, from plants raised in a screenhouse infected with an isolate of MSV obtained recently from a field plant. Except for 1997, insects were caged communally on infected leaves for at least 24 hrs and then caged individually on maize seedlings cv Kawanda Composite A for at least 48 hrs after which time they were removed, and the plants sprayed with insecticide and retained in a leafhopper-free screenhouse for expression of MSD. In 1997 the same individual insects were used for establishing the proportions of MSV transmitters in the field and active transmitters. Insects for this work were either obtained directly from fields as before (Table 25) or from laboratory cultures derived from field populations (Table 26).

	1994	1996		1997	Total	% transmission
Rains	Second	First	Second	First		
Species*						
C. mbila (M)	8/25	12/34	11/35	29/52	60/146	41.1
C. mbila (F)	34/44	43/68	24/42	33/63	134/217	61.8
C. storeyi (M)	3/41	1/2	0/8	6/60	9/111	8.1
C. storeyi (F)	18/74	8/33	10/101	11/38	47/246	19.1

Table 25. Transmission of MSV by field specimens of *C. mbila* and *C. storeyi* given access to streaked leaves (numerator = transmissions; denominator = number of insects tested). M = Male; F = Female.

	C. mbila (M)	*C. mbila* (F)	*C. storeyi* (M)	*C. storeyi* (F)
No. transmitting	10	18	1	4
Proportion transmitting	33%	60%	3%	13%

Table 26. Transmission of MSV by 30 screenhouse-reared specimens of *Cicadulina mbila* and *C. storeyi* given access to streaked leaves. M = Male; F = Female.

Only 1-2% of field-collected *C. storeyi* carried MSV whereas, overall, 10-15% of *C. mbila* carried MSV (Table 24) with up to 47% found in 1997. This is consistent with the latter species being more important in the epidemiology of MSVD. *C. mbila* also had a much higher proportion of active transmitters than *C. storeyi* (Tables 25 and 26) both within natural field populations and within laboratory cultures derived from field populations and in both species the females had higher rates of transmission overall in all experiments. These results are consistent with previous work (Storey 1932).

2.6 *Determine mate seeking behaviour of C.mbila*

Field monitoring of the temporal and spatial patterning of MSVD appearance and incidence and of the movement of the *Cicadulina* vectors of the disease indicated the important role of plant height and the mating behaviour of the insects. Field and laboratory experiments were conducted to elucidate the mechanism of mate seeking, as this behaviour has a considerable impact on the distribution of MSVD within maize plots. By examining the numbers of *Cicadulina* caught on a daily basis it was found that the peaks in numbers were above those expected for random movement into the fields, and suggested an attraction into a field as densities of the vectors increased.

Three experiments were carried out to examine the possible attraction of *C. mbila* to large numbers of their species confined in cages. All three experiments used the same methods for determining attraction:

(a) two cages (50x50x75 cm) were used, one containing *C. mbila* on food plant (young pearl millet covering bottom of cage) and one with food plant only (control)
(b) the cages were set out at two separate stations in a maize field, at a distance so that they did not interfere with each other
(c) short sticky pole traps were set at 30cm away from each side of the cages (4 poles for each cage) and the numbers of *Cicadulina* caught were monitored each day during the experiment
(d) the cages were alternated between the stations on a daily basis (experiments 1 and 2) or moved daily at random between the stations but ensuring that there were equal numbers of readings for each station and each treatment by the end of the experiment (experiment 3)
(e) great care was taken to ensure that the *Cicadulina* could not escape from the experimental cages
(f) Experiment 1 had >1000 *C. mbila* in the cage (for 8 days), Experiment 2 <500 (for 8 days) and Experiment 3 >1500 for 10 days).

The results are shown in Table 27, where it can be seen that above a certain density (in this case > 1000 insects in a cage) there was a significant attraction of wild male *C.mbila* to the cages with insects in. The stations also showed a significant difference. Numbers of females caught in all the experiments were low.

ATTRACTION EXPERIMENT 1 (>1000 IN CAGE)

MALE *MBILA*

Source of Variation	df	SS	MS	F-ratio	Sign
Position	1	175.56	175.56	7.37	**5%**
Treatment	1	203.06	203.06	8.53	**5%**
Day	7	720.94	102.99	4.33	**NS**
Residual	6	142.88	23.81		
Total	15	1242.44			

FEMALE *MBILA*

Source of Variation	df	SS	MS	F-ratio	Sign
Position	1	10.56	10.56	2.36	**NS**
Treatment	1	14.06	14.06	3.14	**NS**
Day	7	37.44	5.35	1.19	**NS**
Residual	6	26.88	4.48		
Total	15	88.94			

ATTRACTION EXPERIMENT 2 (<500 IN CAGE)

MALE *MBILA*

Source of Variation	df	SS	MS	F-ratio	Sign
Position	1	0.06	0.06	0.04	**NS**
Treatment	1	0.56	0.56	0.34	**NS**
Day	7	67.44	9.63	5.85	**5%**
Residual	6	9.88	1.65		
Total	15	77.94			

FEMALE *MBILA*

Source of Variation	df	SS	MS	F-ratio	Sign
Position	1	4.00	4.00	3.00	**NS**
Treatment	1	1.00	1.00	0.75	**NS**
Day	7	2.00	0.29	0.21	**NS**
Residual	6	8.00	1.33		
Total	15	15.00			

ATTRACTION EXPERIMENT 3 (>1500 IN CAGE)

MALE *MBILA*

Source of Variation	df	SS	MS	F-ratio	Sign
Position	1	36.45	36.45	6.98	**5%**
Treatment	1	61.25	61.25	11.72	**1%**
Day	9	45.45	5.05	0.97	**NS**
Residual	8	41.80	5.23		
Total	19	184.95			

FEMALE *MBILA*

Source of Variation	df	SS	MS	F-ratio	Sign
Position	1	0.45	0.45	0.51	**NS**
Treatment	1	0.05	0.05	0.06	**NS**
Day	9	17.45	1.94	2.22	**NS**
Residual	8	7.00	0.88		
Total	19	24.95			

Table 27 Summary of the results from three attraction experiments using different numbers of *C.mbila*

2.7 *Altering the acoustic suitability of maize to disrupt the spread of MSVD*

Much circumstantial and direct evidence has been collected during the MSV project that suggests that *Cicadulina* only enter maize plots and utilise maize plants because they provide an effective environment for mate location. The evidence can be summarised as follows:

a) There are indications from previous workers and from the project that *Cicadulina* do not prefer to feed or oviposit on maize, in fact very few eggs can be found in the field despite large numbers of the vectors being present. Rose (1978) suggested that females move into a field, mate and move out again prior to oviposition.

b) Males are found close to the ground under the canopy of the maize, females are found up in the canopy, particularly in the whorls. Evidence suggests that females, as well as males, move into the field at low level.

c) Male mate-seeking behaviour can be disrupted/reduced by introducing thick vegetation in between the maize stems (i.e. intercropping).

d) It has been shown that *Cicadulina* males instigate acoustic signalling which females then respond to and the males then locate the females by repeated signalling. Since the females are up in the whorls and the males are below, near the ground, the signalling is through the medium of the maize stalk.

e) *Cicadulina* show a preference for maize plants at a height of between 25-40 cm and there are indications that they will go for weaker plants after the majority have passed through that height (i.e. those that are slower growers and go through the preferred height later). The suggestion is that this preferred height might be due to the acoustic suitability of the plants.

f) Since the females come into the maize fields at a low level and there appears to be a selection of the plants they settle on, they may well use acoustic buzzing on the plant to assess its suitability for males to be able to find them through acoustic signalling.

It can be seen from the above that, if the hypothesis is correct, the acoustic suitability of the maize plants plays a major role in the behaviour of the males and females and would be a major reason for the insects to settle and feed on the plants. If, therefore, it was possible to experimentally change the acoustics of the maize plants they would be less suitable for mate seeking and, because maize it not a preferred plant for feeding and ovipositon, MSVD incidence should be reduced.

An experiment to test this idea using standardised hardwood sticks (1x1x50cm) in contact with individual maize plants in order to change acoustics of the plants (Fig 12) was undertaken. The experiment was run over the first 6-8 weeks of maize growth and *Cicadulina* were monitored weekly to show whether females were avoiding plants with sticks. MSVD incidence was assessed on a weekly basis. Forty-eight blocks were planted with one test plant at random/treatment/block, giving 48 plants per treatment. The treatments were:

a) sticks pushed into the ground at an angle across the young maize stems so that they touched the stem but did not impede the growth of the plant.

b) as above, but the stems and the sticks tied together with strips of inner tube which allowed growth and helped to change the acoustics. The tied inner tube was adjusted periodically during the experiment to allow proper growth.

c) sticks pushed into the ground at an angle across the young maize stems so that they touched the stem. At the point of contact, soft foam rubber was attached to the sticks to dampen any vibrations.

d) sticks pushed into the ground at an angle across the young maize stems so that they were not touching the stems. Thus the acoustics of the plants were normal but any visual affect of the sticks was taken into account.

e) maize by itself as a control.

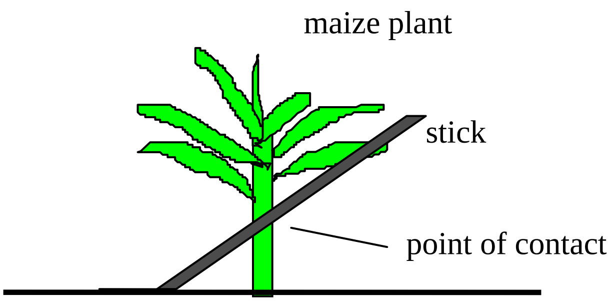

Fig 12 Acoustic experiment: position of stick in relation to the maize plant

Figure 13 shows the rate of increase of MSVD incidence over time for the different treatments. The readings have been taken as zero eight days (20/11/98) after the experiment was set up to allow for any MSV infection prior to the beginning of the experiment to express itself as symptoms. There was a significant difference between the MSVD incidence in plants with sticks against them or sticks with foam against them compared with the control (Table 28).

There was no significant difference between treatments in the numbers of *Cicadulina* counted per plant. Since numbers were comparatively low and the data was collected on a weekly basis this might have been expected.

These results suggest that the acoustics of the plants may be an important factor in the selection by *Cicadulina* of plants on which to settle. This may account for the vector preference for plants at a certain height, which was shown in previous work by the project, and which would have a considerable affect on the distribution of MSVD within fields.

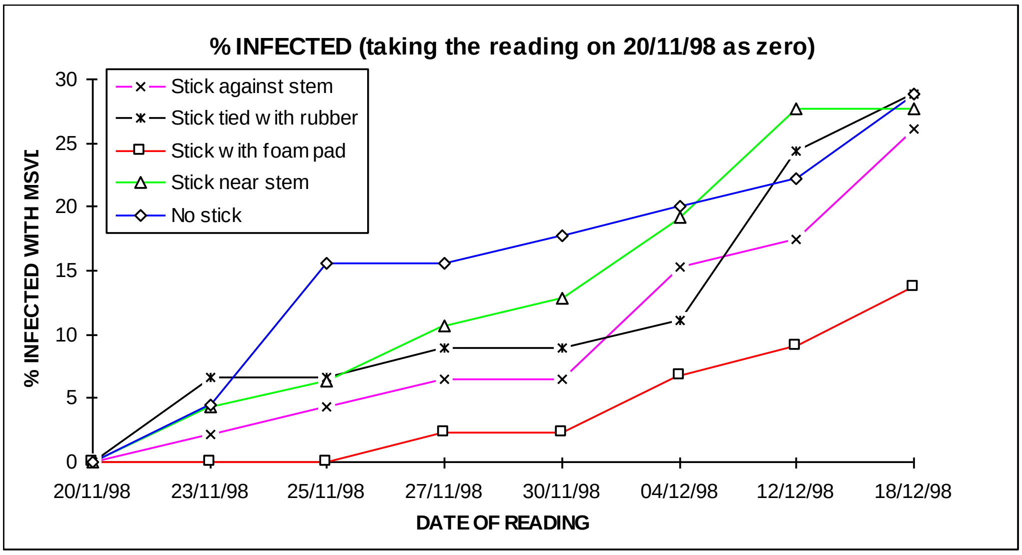

Fig 13 The rate of increase of MSVD incidence in plants where the acoustics have been altered compared with those that have not.

	Coefficients	SE	t Stat	P-value
Intercept	0			
Stick with foam pad	-4.14	1.09	-3.81	**0.02**
Stick against stem	2.64	0.82	3.21	**0.03**
Stick tied with rubber	0.03	0.39	0.08	0.94
Stick near stem	0.52	0.41	1.29	0.27

Table 28 Regression analysis of the results comparing different treatments with the control (untreated plant) to change the acoustics of maize plants

2.8 *Determine crop characteristics associated with vector resistance*

Results from experimental and on-farm work have indicated that *Cicadulina* show varying preferences for different varieties of maize (i.e. different varieties can have varying degrees of streak incidence). It has already been shown that *Cicadulina* appear to select plants on which to settle and feed, thus plants that have been infected with streak may have been preferred to other plants in a plot which have not been infected. Selection of naturally infected plants for streak resistance has the danger of selecting against vector resistance. It is suggested therefore that artificial streak infection used for MSV resistance selection by maize breeders is done with the vectors confined in pots (as used by Barrow, 1992) and not using a release method where the vectors have the chance of selecting the plants on which to settle.

3 *Intercropping studies*

3.1 *Intercropping systems giving a lower incidence of MSVD*

Intercrops of bean and finger millet were tested as a possible means of reducing MSVD incidence by disrupting the mating behaviour of the vectors. A series of three trials were performed (summarised in Table 29). In the first, MSVD incidence two months after sowing was reduced to 14.9% and 17.4% in millet and bean intercrops compared to 29.5% in the pure maize stand, both being significant (see Table 30). The number of male *Cicadulina* spp. caught on sticky pole traps was also significantly reduced relative to the control, but there was little effect on the catch of females (Fig. 14, Tables 31 and 32). There was no significant yield penalty for the millet intercrop but maize yield was 49% lower in the beans intercrop treatment than in the pure stand. In the second trial, the beans were sown at a reduced density and although fewer *Cicadulina* spp. were caught relative to the control (Tables 33 and 34) there was no associated reduction in MSVD incidence. There was a decrease in MSVD incidence in the millet intercrop treatment but the associated maize yield penalty was 89% (Table 35). In the final trial the bean intercrop was again tested but it had no effect on MSVD incidence. These experiments demonstrated that intercropping maize with beans or millet results in reduced vector activity. Vector catches were predominantly male, and catches of males but not females were reduced in the intercrop treatments. However this was not necessarily associated with a reduction in MSVD incidence in maize.

These experiments have shown that, although there is a reduction in male *Cicadulina* activity, female activity is not reduced and any reductions in MSVD incidence in intercropped plots are variable.

	Replicates
Experiment 1:	
maize control: 50cm between rows and 75cm between maize stands within rows	4
maize/millet: maize (50x75cm spacing) intercropped with finger millet (3 rows of millet between rows of maize)	4
maize/beans: maize (50x75cm spacing) intercropped with 2 rows of beans between maize rows (15cm between bean stands)	4
wide spaced maize: maize (75x75cm spacing)	4
Experiment 2:	
maize control sown 5/4: (75x75cm spacing)	4
maize control sown 19/4: (75x75cm spacing)	4
maize/millet sown 5/4: maize (75x75cm spacing) intercropped with 3 rows of finger millet between rows of maize	2
maize/millet sown 19/4: maize (75x75cm spacing) intercropped with 3 rows of finger millet between rows of maize	2
maize/beans 1: maize (75x75cm spacing) intercropped with 2 rows of beans between maize rows (25cm between bean stands)	4
maize/beans 2: maize (75x75cm spacing) intercropped with 2 rows of beans between maize rows and two beans stands between maize stands within maize rows (25x25cm spacing of bean stands)	4
Experiment 3:	
maize control: (75x75cm spacing)	4
maize/beans: maize (75x75cm spacing) intercropped with 2 rows of beans between maize rows and two beans stands between maize stands within maize rows (25x25cm spacing of bean stands)	4
beans control: beans (25x25cm spacing)	4

Table 29. Summary of the intercrop treatments and planting dates for each of the intercrop experiments. All experiments were randomised block designs. The design given for experiment 2 is that after re-sowing (see text).

	1st observation date		2nd observation date	
Treatment	treatment mean ± se	p	treatment mean ± se	p
maize/millet	-1.74±0.15 (14.9%)	0.000	-0.511±0.30 (37.5%)	0.008
maize/beans	-1.56±0.14 (17.4%)	0.000	-0.298±0.29 (42.6%)	0.03
wide spaced maize	-0.99±0.13 (27.1%)	0.49	1.173±0.33 (76.4%)	0.19
maize control	-0.87±0.12 (29.5%)	---	0.608±0.30 (64.7%)	---

Table 30. Experiment 1: effect of intercropping on MSVD incidence. The plots were monitored, two months and three months after sowing, for the incidence of symptoms of MSVD. Predicted means and standard errors (se) for each observation date are given on the logit-transformed scale with the back-transformed mean proportions in parentheses. The p values represent the significance of individual contrasts, using t-tests, between each of the treatments and the control (df= 6 for all t-tests). The treatment effects (increase in deviance resulting from dropping the treatment term from the full model in the analysis of deviance) for the two survey dates were significant at p=0.003 and p=0.007, respectively.

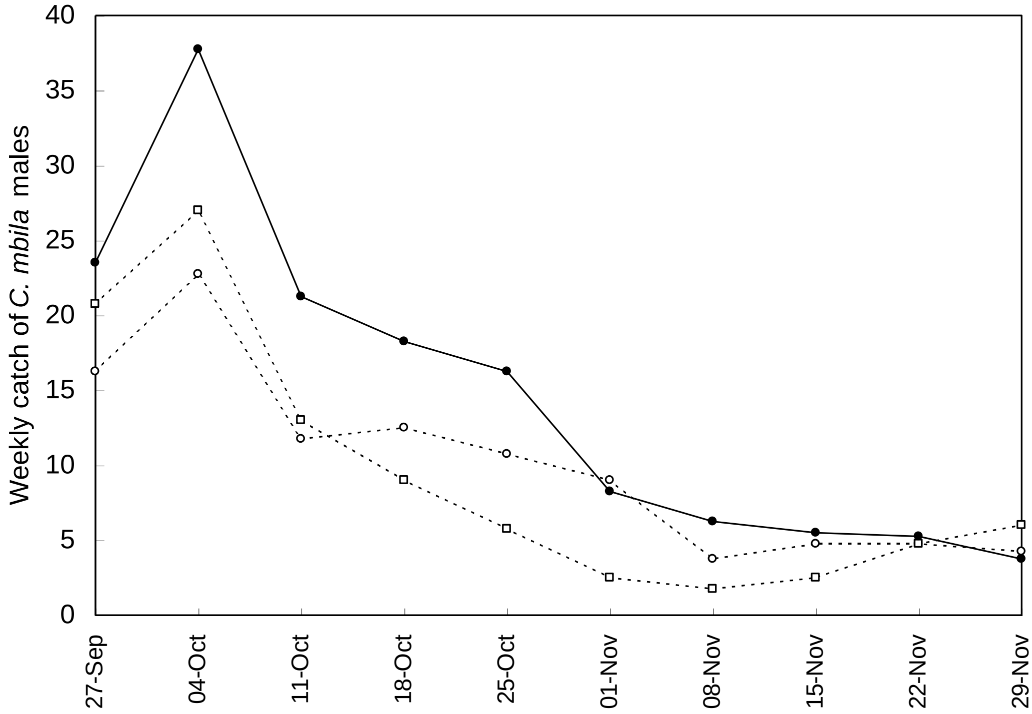

Fig 14 Experiment 1: Average weekly catch of male C. mbila in the different intercrop treatments. Counts are averaged over the four replicate blocks. The experiment was sown on 9/9/94, monitoring of Cicadulina spp. began on 27/9/94. ○ maize with millet intercrop; □ maize with beans intercrop; ● maize control.

	1st observation date		2nd observation date	
Treatments	treatment mean ± se	p	treatment mean ± se	p
C. mbila males				
maize/millet	4.32±0.09 (75)	0.005	4.58±0.09 (98)	0.009
maize/beans	4.31±0.09 (74)	0.005	4.51±0.09 (91)	0.004
wide spaced maize	4.56±0.08 (96)	0.12	4.80±0.08 (122)	0.16
maize control	4.75±0.08 (171)	---	4.96±0.07 (138)	---
C. storeyi males				
maize/millet	3.34±0.06 (29)	0.43	5.04±0.09 (155)	0.45
maize/beans	3.04± 0.07 (21)	0.002	4.22±0.14 (68)	0.002
wide spaced maize	3.37±0.06 (29)	0.62	4.91±0.10 (136)	0.86
maize control	3.41±0.06 (30)	---	4.93±0.10 (138)	---

Table 31. Experiment 1: effect of intercropping on cumulative counts of *C. mbila* and *C. storeyi* males. Counts were analysed approximately two months and three months after sowing. Predicted means and standard errors (se) are given on the log-transformed scale with the back-transformed mean counts in parentheses. The p values represent the significance of individual contrasts, using t-tests, between each of the treatments and the maize control (df= 6 for all t-tests). Overall treatment effects (increase in deviance resulting from dropping the treatment term from the full model in the analysis of deviance) were significant at p=0.013 and p=0.012 for the two observation dates for *C. mbila*, and p=0.009 and p=0.003 for *C. storeyi*.

Treatment	1st observation date treatment mean ± se	2nd observation date treatment mean ± se
C. mbila females		
maize/millet	0.96±0.34 (3)	2.18±0.26 (9)
maize/beans	1.33±0.28 (4)	2.23±0.25 (9)
wide spaced maize	1.45±0.27 (4)	2.38±0.23 (11)
maize control	0.96±0.34 (3)	2.00±0.28 (7)
C. storeyi females		
maize/millet	2.88±0.09 (18)	3.73±0.15 (42)
maize/beans	2.75±0.09 (16)	3.20±0.19 (25)
wide spaced maize	2.96±0.08 (19)	3.74±0.15 (42)
maize control	3.06±0.08 (21)	3.76±0.15 (43)

Table 32. Experiment 1: effect of intercropping on cumulative counts of *C. mbila* and *C. storeyi* females. Counts were analysed approximately two months and three months after sowing. Predicted means and standard errors (se) are given on the log transformed scale with the back-transformed mean counts in parentheses. The p values represent the significance of individual contrasts, using t-tests, between each of the treatments and the maize control. Overall treatment effects (increase in deviance resulting from dropping the treatment term from the full model in the analysis of deviance) were not significant for any of the analyses of deviance (p=0.56 and p=0.77 respectively for *C. mbila* and p=0.34 and p=0.123 respectively for *C. storeyi*). Of t-tests of differences between controls and intercrop treatments only the numbers of female *C. storeyi* in the bean intercrop treatment differed from the control. Probabilities were p=0.030 and p=0.047 (df=6) for the two survey dates, respectively.

	1st observation date		2nd observation date	
Treatment	treatment mean ± se	p	treatment mean ± se	p
C. mbila males				
maize/millet 5/4	3.75±0.34 (42)	0.062	4.32±0.30 (76)	0.10
maize/beans 1	3.41±0.28 (30)	0.005	4.33±0.21 (76)	0.040
maize/beans 2	3.340.28± (28)	0.004	4.23±0.22 (68)	0.023
control 5/4	4.52±0.16 (92)	---	4.93±0.15 (138)	---
maize/millet 19/4	4.00±0.31 (55)	0.052	4.54±0.28 (94)	0.050
control 19/4	4.74±0.14 (114)	---	5.22 ±0.13 (184)	---
C. storeyi males				
maize/millet 5/4	4.03±0.25 (56)	0.61	4.12±0.24 (62)	0.44
maize/beans 1	3.54±0.22 (34)	0.28	3.55±0.22 (35)	0.27
maize/beans 2	3.09±0.28 (22)	0.041	3.11±0.27 (22)	0.037
control 5/4	3.87±0.19 (48)	---	3.88±0.19 (49)	---
maize/millet 19/4	3.99±0.29 (54)	0.86	4.03±0.28 (56)	0.86
control 19/4	3.93±0.18 (51)	---	3.97±0.18 (53)	---

Table 33. Experiment 2: effect of intercropping on cumulative counts of *C. mbila* and *C. storeyi* males. Counts were analysed approximately two months and three months after sowing. Predicted means and standard errors (se) are given on the log-transformed scale with the back-transformed mean counts in parentheses. The p values represent the significance of individual contrasts, using t-tests, between each of the treatments and the maize control (df= 4 for t-tests involving millet intercrop

treatments, and 6 for comparisons with bean intercrop treatments). Overall treatment effects (significance of the increase in deviance resulting from dropping the treatment term from the full model in the analysis of deviance) were significant at p=0.002 and p=0.009 for the two observation dates for *C. mbila*, and p=0.12 and p=0.089 for *C. storeyi*.

	1st observation date	2nd observation date
Treatment	treatment mean ± se	treatment mean ± se
C. mbila females		
maize/millet 5/4	1.68±0.38 (5)	2.66±0.20 (14)
maize/beans 1	2.03±0.22 (8)	2.94±0.12 (19)
maize/beans 2	1.54±0.28 (5)	2.65±0.13 (14)
control 5/4	1.89±0.23 (7)	2.81±0.12 (17)
maize/millet 19/4	2.18±0.31 (9)	3.25±0.15 (26)
control 19/4	2.28±0.19 (10)	2.95±0.16 (19)
C. storeyi females		
maize/millet 5/4	2.26±0.29 (10)	2.68±0.24 (15)
maize/beans 1	1.40±0.32 (4)	1.54±0.28 (5)
maize/beans 2	1.56±0.29 (5)	1.82±0.25 (6)
control 5/4	1.96±0.24 (7)	2.12±0.21 (8)
maize/millet 19/4	3.22±0.24 (25)	3.28±0.21 (27)
control 19/4	2.55±0.18 (13)	2.72±0.16 (15)

Table 34. Experiment 2: effect of intercropping on cumulative counts of *C. mbila* and *C. storeyi* females. Counts were analysed approximately two months and three months after sowing. Predicted means and standard errors (se) are given on the log-transformed scale with the back-transformed mean counts in parentheses. The p values represent the significance of individual contrasts, using t-tests, between each of the treatments and the maize control (df= 4 for t-tests involving millet intercrop treatments, and 6 for comparisons with bean intercrop treatments). Overall treatment effects (significance of the increase in deviance resulting from dropping the treatment term from the full model in the analysis of deviance) were significant at p=0.33 and p=0.14 for the two observation dates for *C. mbila*, and p=0.004 and p=0.001 for *C. storeyi*. Of t-tests of differences between controls and intercrop treatments only the numbers of female *C. storeyi* in the millet intercrop treatment sown on 19/4 were close to significance. Probabilities were p=0.053 and p=0.058 for the two survey dates, respectively.

	1st observation date	2nd observation date
Treatment	treatment mean ± se	treatment mean ± se
maize/millet 5/4	-2.35±0.39 (8.7%)	-1.73±0.47 (15.0%)
maize/beans 1	-1.75±0.23 (14.8%)	-1.32±0.30 (21.1%)
maize/beans 2	-1.66±0.22 (16.0%)	-1.20±0.29 (23.1%)
control 5/4	-1.82±0.23 (14.0%)	-1.47±0.32 (18.7%)
maize/millet 19/4	-3.36±0.68 (3.4%)	-1.89±0.59 (13.2%)
control 19/4	-1.55±0.21 (17.6%)	-0.38±0.25 (40.6%)

Table 35. Experiment 2: effect of intercropping on MSVD incidence. The plots were monitored two months and three months after sowing for the incidence of symptoms of MSVD. Predicted means and standard errors (se) for each observation date are given on the logit-transformed scale with the back-transformed mean proportions in parentheses. The p values represent the significance of individual contrasts, using t-

tests, between each of the treatments and the control (df= 4 for t-tests involving millet intercrop treatments, and 6 for comparisons with bean intercrop treatments). The overall treatment effects, calculated in the analysis of deviance, for the two survey dates were not significant, p=0.094 and p=0.075, respectively. t-tests between intercrop treatments and the appropriate control were significant only for the millet intercrop treatment sown on 19/4, p=0.012 and 0.018 respectively.

4 *Modelling studies*

4.1 *Cropping strategy modelling (using lattice models)*

The original intention was to construct a model as a spatial lattice of fields to investigate interactions in an ecosystem of mixed crops and maize varieties. In fact, a different approach was taken. The key issue was gene frequency change within the crop and this was examined in relation to selection processes within the crop and to the proportion of pollen that arrives from other fields (see 4.2 below). An analysis was performed by examining the sensitivity of the model to parameter changes rather than estimating these parameters from an explicitly spatial model.

4.2 *Resistance dynamics modelling*

A gene-frequency model, using 12 scenarios (Table 36), was constructed to investigate the causes of a reported decline in resistance in farmer saved seed of the open-pollinated maize cultivar, Longe1. In particular, the question was investigated of whether a positive linkage between susceptibility to streak and cob size combined with selection of large cobs for seed by farmers could contribute significantly to this decline.

scenario		genotype frequencies after 20 generations			allele frequencies		estimated yield at disease incidence of	
		RR	RS	SS	R	S	25%	100%
1	R-allele codominant	0.81	0.18	0.01	0.90	0.10	0.92	0.81
2	R-allele dominant	0.80	0.19	0.01	0.90	0.10	0.92	0.85
3	R-allele recessive	0.74	0.24	0.02	0.86	0.14	0.91	0.76
4	codominance, large cobs also contain more seed	0.78	0.21	0.01	0.88	0.12	0.92	0.81
5	1% of pollen from an SS source	0.72	0.26	0.02	0.85	0.15	0.92	0.80
6	5% of pollen from an SS source	0.45	0.44	0.11	0.67	0.33	0.91	0.73
7	10% of pollen from an SS source	0.24	0.50	0.26	0.49	0.51	0.90	0.67
8	streak incidence only 5%	0.64	0.32	0.04	0.80	0.20	0.95	0.74
9	lower s.d. of cob weight	0.58	0.36	0.05	0.76	0.24	0.91	0.77
10	mean cob weights of RR genotype: disease-free 0.9, diseased 0.8	0.59	0.36	0.05	0.60	0.40	0.88	0.74
11	initial genotype frequencies RR(0.64), RS(0.32), SS(0.04)	0.62	0.33	0.04	0.79	0.21	0.91	0.78
12	initial genotype frequencies RR(0.25), RS(0.5), SS(0.25)	0.20	0.49	0.30	0.45	0.55	0.90	0.66

Table 36 Scenarios 1-12: the genotype frequencies after 12 generations of farmer selection; the relative yield of this combination of genotypes if streak incidence was 25%; and the relative yield if 100% of plants were infected by streak.

In the model resistance to streak was assumed to be controlled by a single major gene with codominance (Rodier *et al.*, 1995; Kim *et al.*, 1989), which either directly affects maize yield or is strongly linked to genes which do. The genotype frequencies in newly purchased seed of Longe1 were taken as 0.81 (RR: resistant homozygote), 0.09 (RS: heterozygote) and 0.01 (SS: susceptible homozygote) which correspond to allele frequencies of 0.9(R: resistant allele) and 0.1(S: susceptible allele).

The incidence of streak was taken as 25% (the average end-of-season incidence in the various 40x60 monitoring plots) and the proportion infected was assumed to be the same for all genotypes. However symptoms were taken to be considerably more severe in susceptible plants. This corresponds to the type of resistance found in Longe1. Weights of cobs from uninfected plants with genotype RR were assumed to be slightly inferior to those from uninfected SS plants. A 5% difference was assumed on the basis that breeders would probably consider anything larger to be unacceptable.

The proportions of each of the six classes of cob (streaked RR, RS, and SS; and unstreaked RR, RS and SS) above a given cut-off weight were calculated using statistics of the area under the upper tail of the normal distribution. Each generation the cut-off weight i.e. the minimum weight for a cob to be selected was adjusted iteratively until the overall proportion of cobs selected was 0.5%. The simulation was repeated for 12 generations of maize, the maximum number a generations for which a farmer is likely to have selected since the release of Longe1 in Uganda in 1991, and the changes in the relative genotype frequencies were also recorded each generation. The model was then adjusted to investigate a number of different scenarios.

When the R-allele was assumed to be codominant its frequency decreased by only

0.002 over 12 generations (scenario 1, see Fig.15). Thus the negative selection for resistance exerted by farmers approximately balanced the selective effects of streak at an incidence of 25%. If farmer selection, alone, was the reason for loss of the R-allele average streak incidence would have to be a lot lower than initially assumed and/or the s.d.of cob weight would have to be lower and/or the negative effect of resistance on cob weight would have to be greater than estimated initially.

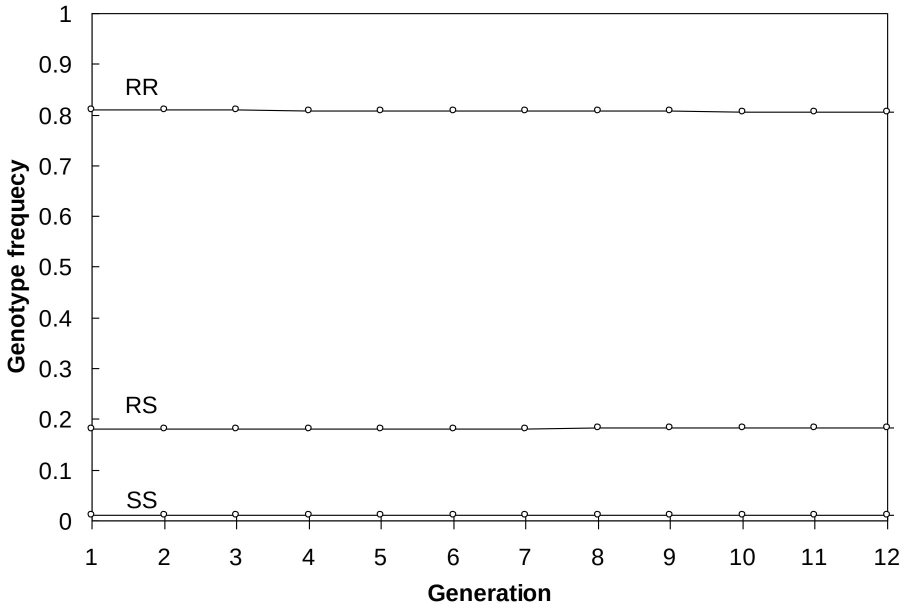

Fig. 15 Simulation of the effects of selection method on resistance: R-allele is codominant (scenario 1). There is little change in genotype frequencies over 12 generations.

Cross-pollination levels of 5% and 10% also resulted in striking decreases in R-allele frequency. We do not at present have any idea of the level of cross-pollination though plot sizes are generally quite small and many farmers do still grow susceptible local land races or susceptible hybrids. 200-500m distance is required between maize plots to prevent cross-pollination (Baktash, 1984; Airy, 1955). Paterniani and Stort (1974) estimated that 50% of the kernels on a maize plant resulted from pollination by pollen of plants within a radius of 12m. Thus 50% must originate from further than 12m. These estimates suggest that there could be considerable cross-pollination by susceptible varieties, particularly in plants on the edges of the plots. However cross-pollination rates are heavily dependent on environmental conditions, synchrony of flowering and relative sizes of the pollen source and sink. Contamination with susceptible material could also come about as a result of gap-filling with susceptible material or mixing the seed before sowing.

5. *Development of management strategies*

Two main strategies that emerged for managing the disease were:

Given the complexity of the farmers' situation, improve farmer knowledge of MSVD so they can make informed decisions about managing the disease. This includes information regarding practices which are likely to encourage (e.g. planting under shade) and discourage (e.g. planting early and intercropping) MSVD.

Making reliable seed available to farmers is essential but beyond the scope of this project to address the institutional problems directly. Therefore, through training and provision of Longe1 from Namulonge, the idea of empowering farmers to produce their own seed through controlled pollination in the study villages was explored.

6. *Determine crop characteristics associated with vector resistance*

Results from experimental and on-farm work (see 2.2 above) have indicated that *Cicadulina* show varying preferences for different varieties of maize (i.e. different varieties can have varying degrees of streak incidence). An example of an experiment, using four replicates in random blocks, is given in Table 38 showing that two varieties (Hybrid B, P = 0.004 and Iganga local, P= 0.02) showed a considerable reduction in MSVD incidence over a more susceptible variety (KWCA).

VARIETY	No STANDS (out of 100)	LEAF INFECTED	SEVERITY	No WITH STREAK	% WITH STREAK
KWCA	95.75	4.41	3.05	19.50	20.44
LONGE 1	93.25	3.99	3.03	14.75	15.90
HYBRID B	94.00	4.29	2.30	7.00	7.43
LUKUNYU (local)	87.00	4.49	2.81	19.75	22.61
KASAMBYA (local)	95.25	4.11	2.74	14.50	15.31
IGANGA (local)	87.00	4.18	3.20	7.00	8.15

Table 38 Example of the proportions of plants found with MSVD symptoms using four replicated plots in random blocks.

In addition to the level of severity (virus resistance), observations of proportions of plants infected with MSVD are already made as a routine reading when maize breeding/selection work is being done. However, selection has primarily been done for virus resistance. Since it has been shown that *Cicadulina* appear to select plants on which to settle, plants that have already been infected with streak may be preferred to other plants in a plot which have not been infected. Selection of naturally infected plants for streak resistance has the danger of selecting against vector resistance. It is suggested therefore that artificial streak infection be used for MSV resistance selection by maize breeders. This can be done with the vectors confined in pots (as used by Barrow, 1992) and not using a release method where the vectors have the chance of selecting the plants on which to settle.

Because provision of good quality seed (including MSV resistance) was of major importance to farmers (see above) the concentration of work moved towards understanding the reasons for farmer-perceived MSV resistance breakdown and empowering the farmers to start producing their own quality maize seed.

7. Additional activity: Workshop

The end-of-project workshop was held and well attended with participants from Uganda, Kenya and South Africa representing official programmes, researchers, extensionists, NGOs, seed producers and farmers (see Appendix 8 for the programme and list of participants). The proceedings have been submitted to CPP management in final draft form for their input prior to distribution to participants and interested parties. The importance of seed quality and availability was of major importance to all participants.

Contribution of Outputs

The project identified and addressed the need to improve farmers' knowledge of MSVD to enable them to make informed decisions about managing their maize crop.

The project has shown that it is possible for farmers to select and produce their own maize seed. Farmers are keen to understand and have proved able to benefit from knowledge on how to select and maintain, from season to season, open-pollinated varieties with preferred characteristics.

The Ugandan Cereals Programme has benefited from the observations and experiments made during the course of the project and has incorporated some of the techniques into their breeding programmes. The project has encouraged links between researchers and extensionists and NGOs operating in the project areas.

The project has established good rapport and collaboration with groups of farmers in key maize growing areas which will continue (e.g. with the termite project and a short project to continue with the on-farm seed selection study) and which will form good bases from which to continue developing pest management and cropping strategies.

It has been shown that various farming practices can affect the incidence of MSVD and this can be explained by the knowledge of vector behaviour. The most important are summarised below:

(1) Intercropping.
Having shown that the *Cicadulina* mate-seeking activity within maize appeared important, it was thought that if the spaces between the maize plants were filled with a dense, low crop then, in particular, male activity would be hampered and therefore the spread of MSD would be reduced. Over several seasons, intercropping of maize with beans and millet was examined. The results showed clearly that the activity of male vectors was considerably reduced (as measured using pole traps) but reduction in streak only occurred and when the densities of the intercrops were particularly high and to the detriment of the maize yield.

(2) Time of planting.
At the beginning of a maize growing season the proportion of *Cicadulina* carrying MSV is very low. As more and more maize plants are infected the number of leafhoppers acquiring virus and spreading it increases. Maize fields planted later than others in an area can have far more plants infected with the disease because there are many more leafhoppers around carrying the virus. In addition, because the leafhoppers appear to prefer maize at a height of 25-40 cm, and it is then that the virus spreads quickly in the fields, a maize field planted later than others in an area will be at the preferred height, collect leafhoppers and increase the chances of heavy infection.

(3) Gap filling.
Replanting where seeds have not germinated will also increase the amount of MSVD because of the leafhoppers' preference for the younger plants in the field and because the numbers of leafhoppers carrying the virus will be high by the time these new plants reach the height of 25-40 cm. This does not necessarily mean that gap filling should be discouraged for many of the plants may still produce a cob of some sort, which is better than none at all from empty stands.

(4) Roguing.
Removing diseased plants does not really help because there are many leafhoppers with virus spreading MSV and plants that are pulled out might grown on to a small cob.

(5) Spacing.
Babatope Alo (1993) has shown that the closer the spacing, the higher the incidence of streak. It is therefore important to understand the relationship between plant density, disease incidence and agronomic characteristics and yield.

(6) Shade.
It is strongly recommended that maize is not grown in the shade as a greater proportion are likely to become infected, and at an earlier stage in growth which would ensure greater crop loss.

(7) Vector resistance.
There are indications from experimental and on-farm work that *Cicadulina* show varying preferences for different varieties of maize. It is suggested therefore that when maize breeders select for MSVD resistance they challenge plants with infected vectors confined in pots (as used by Barrow, 1992) and do not use a release method where the vectors have a chance of selecting the plants on which to settle.

(8) Growing MSVD-resistant varieties.
Although MSVD-resistant varieties can be infected they show a good tolerance to the disease with very little leaf area lost to streaking. Thus little or no crop loss due to MSVD occurs. One problem that was found on-farm was a farmer perceived "break down" in resistance to MSVD in the Ugandan open-pollinated variety Longe1 1. On-farm, Longe1 is being grown amongst other open-pollinated varieties of maize ("local") and therefore is cross-pollinated. Investigations suggest that farmers may be selecting out MSVD resistance by selecting large seeds for re-planting. Because Longe1 seeds are smaller than those of many local varieties, selection of large seeds from cross-pollinated plants selects towards the local variety and not Longe1. This was addressed by showing farmers how to isolate their Longe1 to avoid cross-pollination.

Dissemination outputs

Workshop

Proceedings have been produced
*See activity **6** above*

Research Papers

GIBSON, R. W. and PAGE, W. W. (1997). The determination of when maize plants were infected with maize streak virus from the position of the lowest diseased leaf. *African Crop Science Journal,* **5:** 189-198.

RILEY, J. R., DOWNHAM, M. C. A. and COOTER, R. J. (1997). Comparison of the performance of *Cicadulina* leafhoppers on flight mills with that to be expected in free flight. *Entomologia Experimentalis et Applicata,* **83:** 317-322.

SMITH M C, PAGE W. W., HOLT J. and KYTERE, D. (submitted). Maize streak virus disease: spatial dynamics of epidemic development within fields. *International Journal of Pest Management*

PAGE, W. W., SMITH, M. C. and HOLT, J. (submitted). The impact of intercrops on maize streak virus disease in maize. *Annals of Applied Biology*

Papers presented at scientific meetings

PAGE, W.W. Behaviour of leafhopper vectors (*Cicadulina* spp.) within maize and its importance in increasing mating opportunities. Presentation of an invited paper to The XX International Congress of Entomology, Florence, Italy, 25-31 August 1996

Posters presented at scientific meetings

KYETERE, D. AND PAGE W. W. (also submitted as a paper) Vector behaviour in relation to maize streak virus epidemiology. The Sixth Eastern and Southern Africa Regional Maize Conference. Maize Production Technology for the Future: Challenges and Opportunities. 21-25 September, 1998.

Manuscripts in preparation

Authors to be decided. (In prep.). Analysis of the relationship between rates of maize streak virus disease progress and vector catches.

Smith M C and others (in prep). Dynamics of maize streak virus disease resistance in farmer-selected maize.

Internal reports

Various back-to-office reports and quarterly and annual reports over the course of the project.

Situation Analysis of maize growers in four villages in Tororo and Iganga districts, with particular emphasis on maize streak virus disease. National Maize Programme, Namulonge AARI, Uganda and NRI, Chatham, UK. March 1997

Follow-up to situation analysis of maize growers in Tororo and Iganga districts: MSV knowledge and dissemination. Richard Lamboll (NRI), Bill Page (NRI), Twaha Kalule (National Maize Research Programme, NARO). October 1997

Village-based research - access to maize seed: Towards empowering the farmer. Paper presented at the workshop.

LAMBOLL, R., PAGE, W. W. and KALULE, T. (1997). Follow-up to situation analysis of maize growers in Tororo and Iganga Districts: MSV knowledge and dissemination.

Other dissemination of results

Leaflet in both English and Luganda:
Maize Streak Virus Disease: An information Sheet.
Distributed to farmers, seed merchants and interested NGOs by the National Cereals Programme and by IDEA (USAID) programme. Copies attached as Appendix 9

Follow-up indicated/planned:

The on-farm studies, particularly those related to seed selection by farmers, have reached a point where they could become fully participatory. An outline proposal as given, below:

Title**:** Elements of a follow-up to maize seed production in Namukubembe and Bugodi villages, Iganga district, Uganda.

Background: During the 1998b planting season farmers in Namukubembe and Bugodi villages (Iganga district) received basic training on seed production from Namulonge Cereals Programme staff facilitated by the MSVD project. The outcome of this was Longe1 seed produced in the villages. An initial evaluation showed enthusiasm from the farmers involved, although at this stage the quality of the seed is not clear.

Aim: To evaluate the sustainability of community/ farmer-based seed production in mid-altitude Uganda

Who would be involved? Namukubembe village farmers group, St Ngondwe farmers group (Bugodi village), National Cereals Programme (NAARI), FOSEM (NGO), NRI.

Activities:
1. Continue to provide appropriate training and information on seed production to farmers groups in Namukubembe and Bugodi villages.
2. Monitor seed production activities in Namukubembe, Bugodi and selected FOSEM

sites over the 1999a and 1999b seasons.
3. Evaluate the process and the output from both a farmer and researcher perspective.

Impact: If evaluation indicates the approach is appropriate, scale-up activities to other villages through the FOSEM network. The collaborative links established through this work cold be built upon to develop a broader-based project on IPM in maize cropping systems in the future.

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Compiled by WW Page, Project Field Manager

APPENDIX 1.

Summary of methods used for the situation analysis

MSV SURVEY

SITE (VILLAGE) SELECTION

Criteria for selection

(1) Major maize producing area
(2) Transact across Tororo (2) and Iganga (3) reflecting changing rainfall.
(3) MSV has been reported as a problem in these villages

DAOs of Tororo (6 counties) and Iganga (5 counties) to help select sites using the above criteria.

FARMER SELECTION

Farmers will be interviewed in various groups. The make-up of the groups should reflect different 'types' of farmers.

Possible ways include grouping farmers according to:
(1) Area of land cultivated
(2) Gender
(3) Wealth
(4) Use of hired labour
(5) Extent of commercial production

Number of groups per village - 6?
Size of group - smaller allows greater participation

TECHNIQUES TO ADDRESS CHECKLIST POINTS

(1) Background to the farming system
Main crops being grown
General trends (past, present and future) in cropping systems
Importance of maize compared to other crops (cash, food, other)

(2) Maize farming practices
How is maize grown?
Describe all practices (from procurement of seed to post-harvest activities)
Who carries out activities?
When are activities carried out?
Give reasons where appropriate

(3) Identification and prioritisation of constraints on maize production
Problem/ constraints
Cause
Current farmer approaches to dealing with problem
Farmer needs

(4) Farmers perception of MSV
Awareness of symptoms - in which year first noticed
Awareness of cause
Associated factors
Crop losses attributed to MSV

(5) Farmer practices for the control of maize streak
Specific practices
Specific inputs

(6) Aspects of seed
Varieties grown
Source of varieties grown
Affect of streak on different varieties
System of seed selection

(7) Farmers needs with respect to MSV
What are farmers needs?
How do farmers think their needs should be addressed?

APPENDIX 2

Ranking of crops for food and cash in the study villages

Kisoko and Ajuket, Tororo district

Kisoko

Food crops			Cash crops		
Elders	**Women**	**Men**	**Elders**	**Women**	**Men**
F.millet	F.millet	Cassava	N/A	Cotton	Cotton
Cassava	Cassava	F.millet		Rice	Rice
Sorghum	S.potato	Sorghum		F.millet	Maize
S. potato	Maize	Maize		G.nuts	Soya
Maize	Sorghum	S.potato		Maize	G.nuts
Rice	G.nuts	Beans		Sugar c.	Cabbage
G. nuts	Beans	G.nuts		Cassava	Banana
Cowpea	Rice	Rice			Beans
Beans		Cowpea			Tomato
Banana		Soya			Sugar c.

Ajuket

Food crops			Cash crops		
Elders	**Women**	**Men**	**Elders**	**Women**	**Men**
F.millet	F.millet	Maize	Rice	F.millet	Maize
Maize	Cassava	Cassava	Cotton	Maize	F.millet
Cassava	Sorghum	Sorghum	Soya	S.potato	S.potato
S.potato	Maize	F.millet	S.potato	Cassava	Cotton
Sorghum	S.potato	S.potato	Maize	G.nuts	G.nuts
Banana	Beans	Beans	Banana	Simsim	Rice
Beans	G.nuts	G.nuts	Onion	Cowpea	Beans
G.nuts	Simsim	Soya	Cabbage	Sorghum	Soya
Cowpea	Suk-wiki	Rice		Cotton	Simsim
Rice	Amar.	Amar.		Suk-wiki	Tomato

Kisoko

Food Crop	**Eld**	**Wom**	**Men**	**All**	**Cash Crop**	**Eld**	**Wom**	**Men**	**All**
F.millet	1	1	2	4	Cott	NA	1	1	2
Cassava	2	2	1	5	Rice	NA	2	2	4
Sorghum	3	5	3	11	Maize	NA	5	3	8
S. potato	4	3	5	12	G.nut	NA	4	5	9
Maize	5	4	4	13	F.mil	NA	3	NA	
G.nuts	7	6	7	20	Soya	NA	NA	4	
Beans	9	7	6	22					
Rice	6	8	8	22					

Ajuket

Food Crop	**Eld**	**Wom**	**Men**	**All**	**Cash Crop**	**Eld**	**Wo**	**Me**	**All**
F.mil.	1	1	4	6	Maize	5	2	1	8
Cass	3	2	2	7	F.mil	NA	1	2	
Maize	2	4	1	7	S.pot	4	3	3	10
Sorg	5	3	3	11	Cott	2	9	4	15
S.pot	4	5	5	14	Rice	1	11	6	18
Beans	7	6	6	19	G.nuts	NA	5	5	
G.nut	8	7	7	22	Soya	3	NA	8	
Rice	10	NA	9		Simsim	NA	6	9	

APPENDIX 2 (cont)

Mamukubembe and Bugode, Iganga district

Mamukubembe						**Bugode**					
Food crops			**Cash crops**			**Food crops**			**Cash crops**		
Elders	**Women**	**Men**	**Elders**	**Women**	**Men**	**Elders**	**Women**	**Men**	**Elders**	**Women**	**Men**
S.potato	Maize	S.potato	Coffee	Coffee	Maize	S.potato	S.potato	Maize	Coffee	Coffee	Coffee
Maize	S.potato	Cassava	Maize	Maize	Coffee	Maize	Maize	Beans	Maize	Beans	Maize
Beans	Beans	Maize	Beans	Beans	Beans	beans	Cassava	S.potato	Soya	Maize	Beans
Soya	Banana	F.millet	Veg		S.potato	Cassava	Beans	G.nuts	Beans	Tomato	S.potato
F.millet	F.millet	Banana	S.potato		Tomato	Banana	Banana	Cassava	Banana	Cabbage	Rice
Rice	G.nuts	Beans	Soya		Soya	Soya	G.nut	F.millet	F.millet	S.potato	Soya
Banana	Soya	G.nuts	Rice		Cabbage	Veg	Soya	Rice	S.potato	Soya	Cassava
G.nuts	Simsim	Simsim	Sugar c.		G.nuts	F.millet	Amer	Banana	G.nuts	Eggplant	Sorghum
Sugar c.	Yam	Cabbage	Banana		F.millet	G.nuts	Entula	Esobyo	Pineapp.	Passion	F.millet
Veg	Entula	Tomato	Passion		Sugar c.	Simsim	Eggplant	Amer	Rice	G.nuts	Tomato

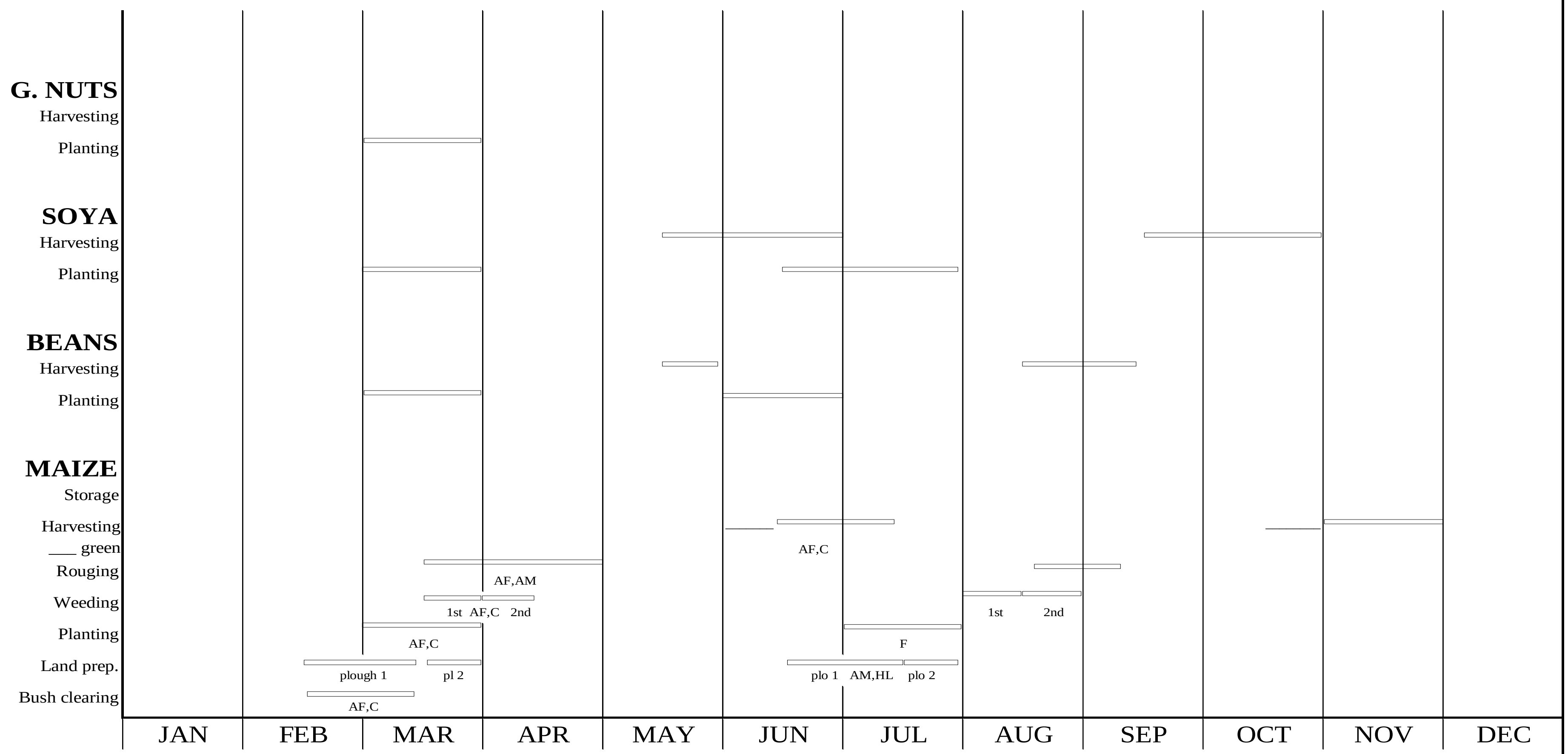
Mamukubembe										**Bugode**									
Food					**Cash**					**Food**					**Cash**				
Crop	**Eld**	**Wom**	**Men**	**All**	**Crop**	**Eld**	**Wom**	**Men**	**All**	**Crop**	**Eld**	**Wom**	**Men**	**All**	**Crop**	**Eld**	**Wo**	**Me**	**All**
S.potato	1	2	1	4	Coff	1	1	2	4	S.pot	1	1	3	5	Coff	1	1	1	3
Maize	2	1	3	6	Maize	2	2	1	5	Maize	2	2	1	5	Maize	2	3	2	7
Beans	3	3	6	12	Beans	3	3	3	9	Beans	3	4	2	9	Beans	4	2	3	9
F.millet	5	5	4	14	S.pot	5	NA	4		Cass	4	3	5	12	Soya	3	7	6	16
Banana	7	4	5	16	Soya	6	NA	6		Ban	5	5	8	18	S.pot	7	6	4	17
G.nut	8	6	7	21						G.nuts	9	6	4	19					

APPENDIX 3
Crop calendars from study villages

CALENDAR OF MAIZE GROWING AND INTERCROPS

KISOKO: WOMEN

AF = adult female AM = adult male F = family CF = child female CM = child male HL = hired labour

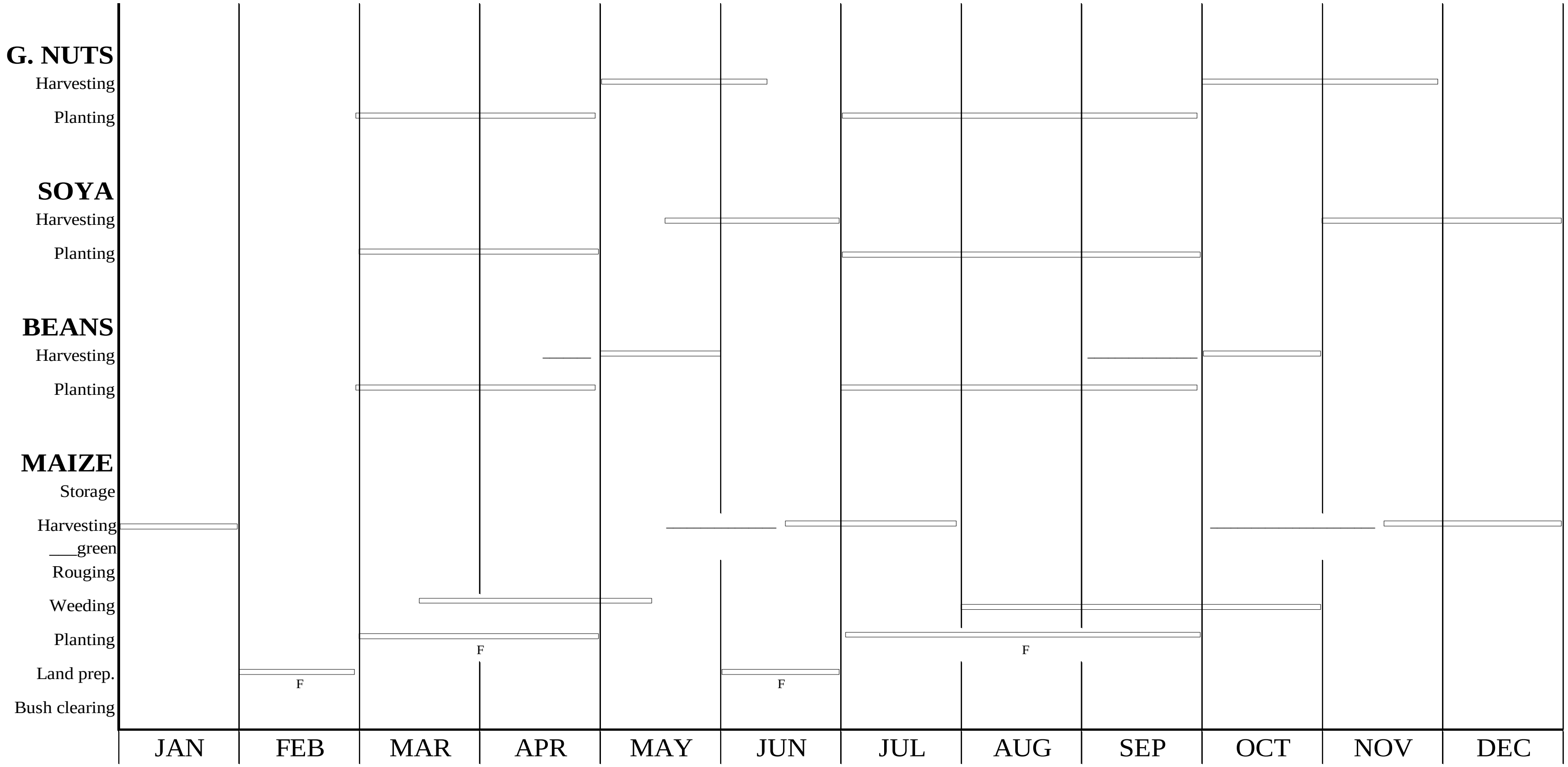


APPENDIX 3 (cont)

CALENDAR OF MAIZE GROWING AND INTERCROPS

KISOKO: MEN

AF = adult female AM = adult male F = family CF = child female CM = child male HL = hired labour

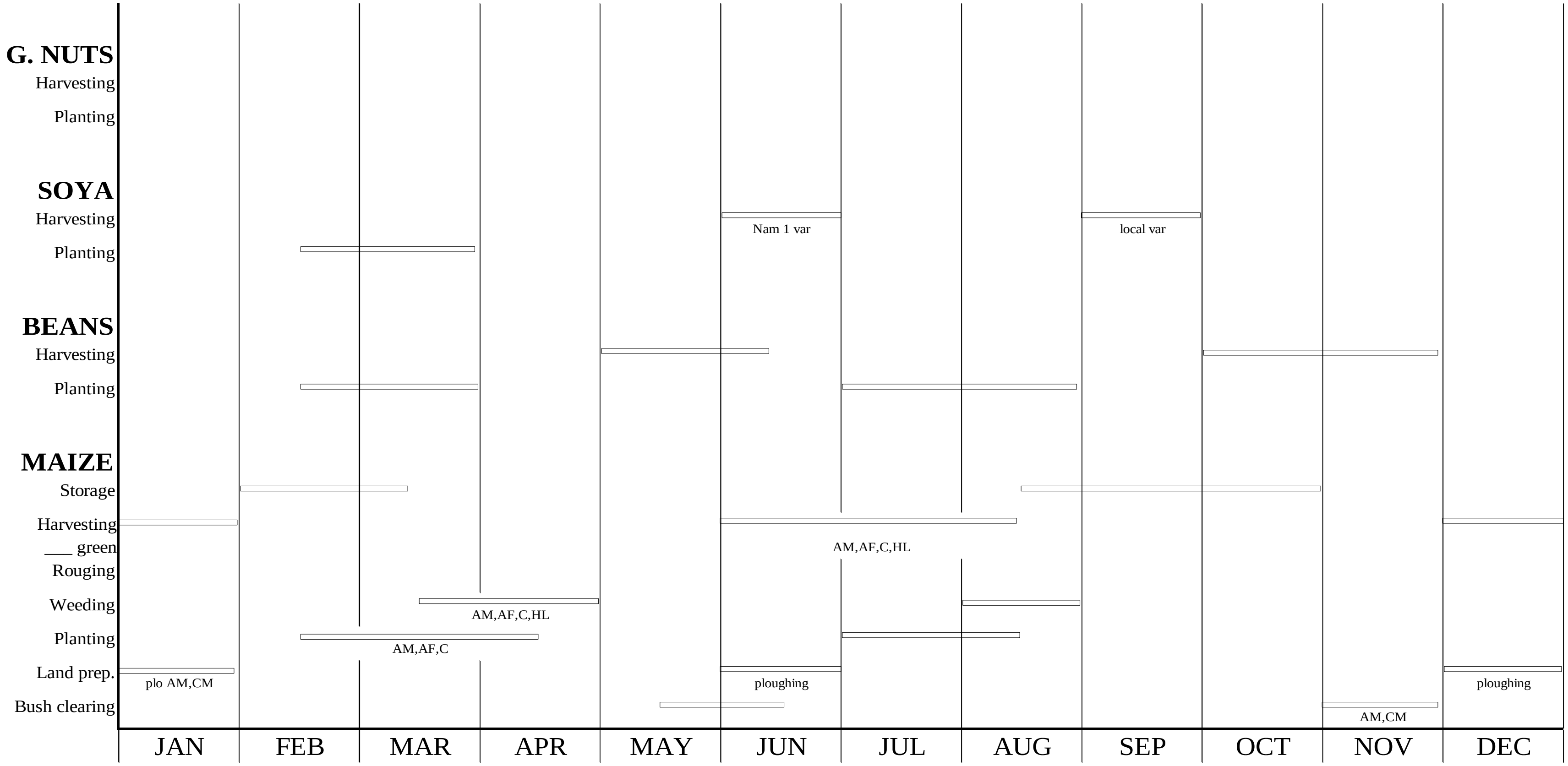


APPENDIX 3 (cont)

CALENDAR OF MAIZE GROWING AND INTERCROPS

AJUKET: MEN

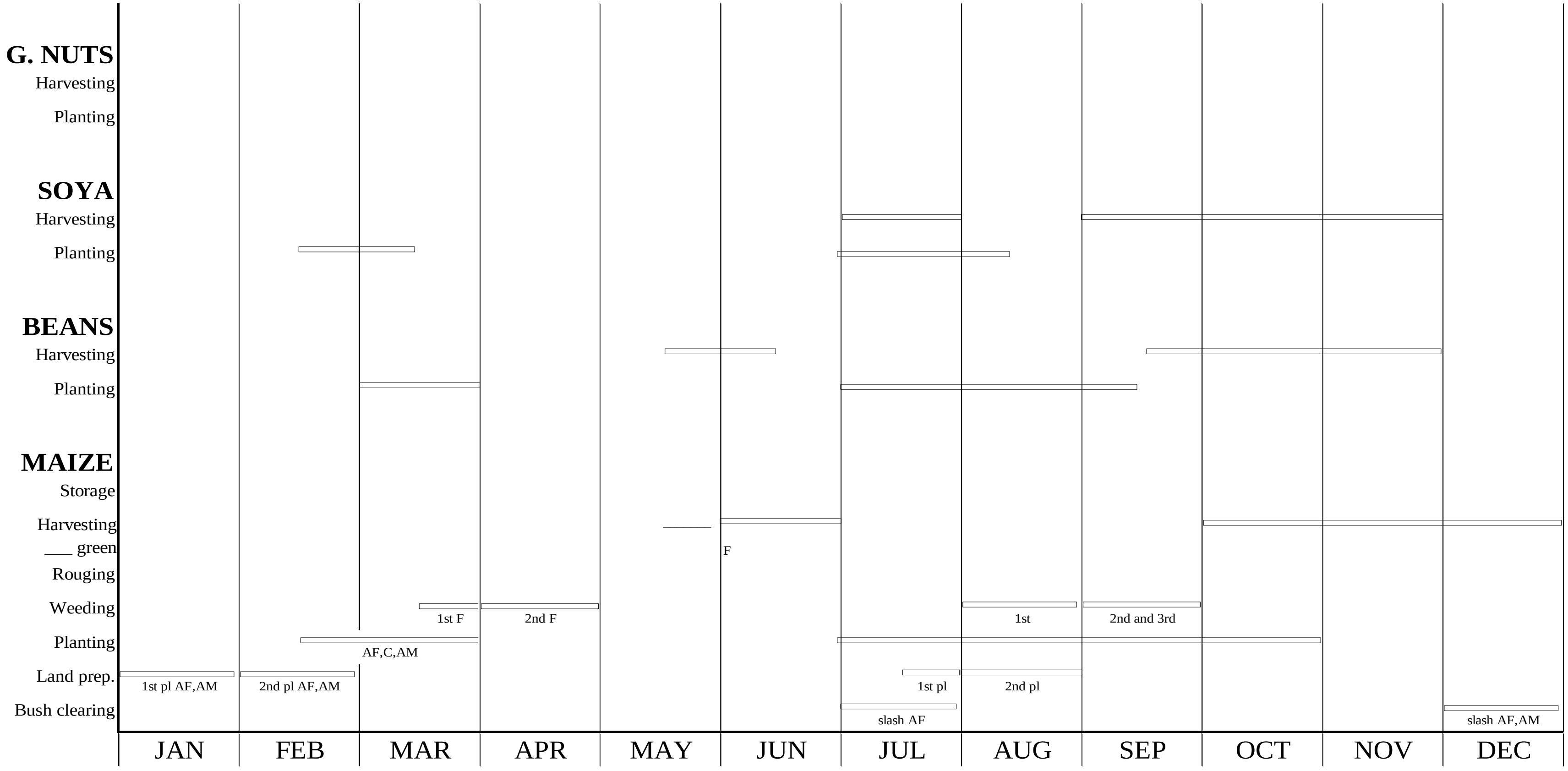
AF = adult female AM = adult male F = family CF = child female CM = child male HL = hired labour



APPENDIX 3 (cont)

CALENDAR OF MAIZE GROWING AND INTERCROPS

MAMUKUBEMBE: WOMEN AF = adult female AM = adult male F = family CF = child female CM = child male HL = hired labour

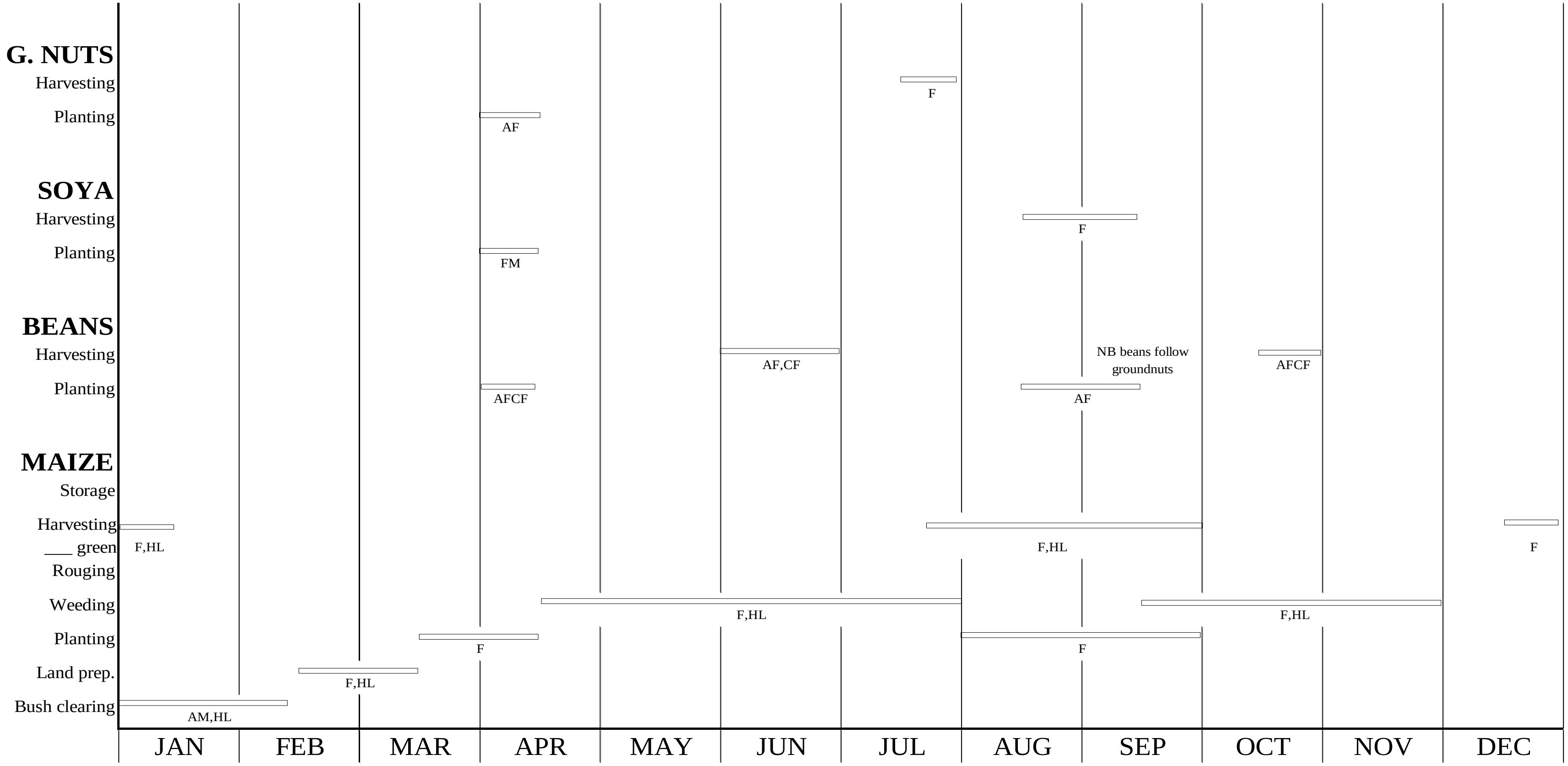


APPENDIX 3 (cont)

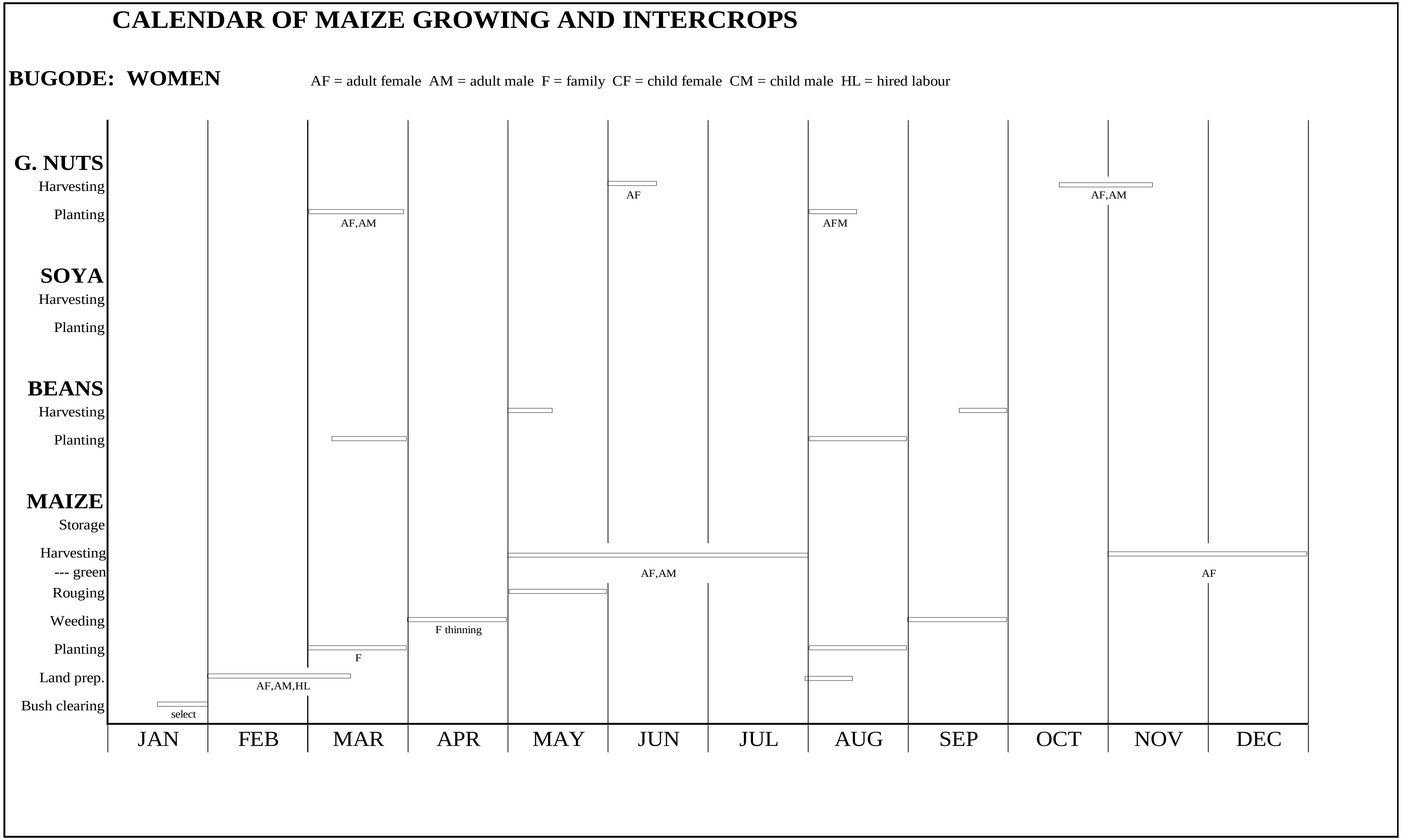
CALENDAR OF MAIZE GROWING AND INTERCROPS

MAMUKUBEMBE: MEN

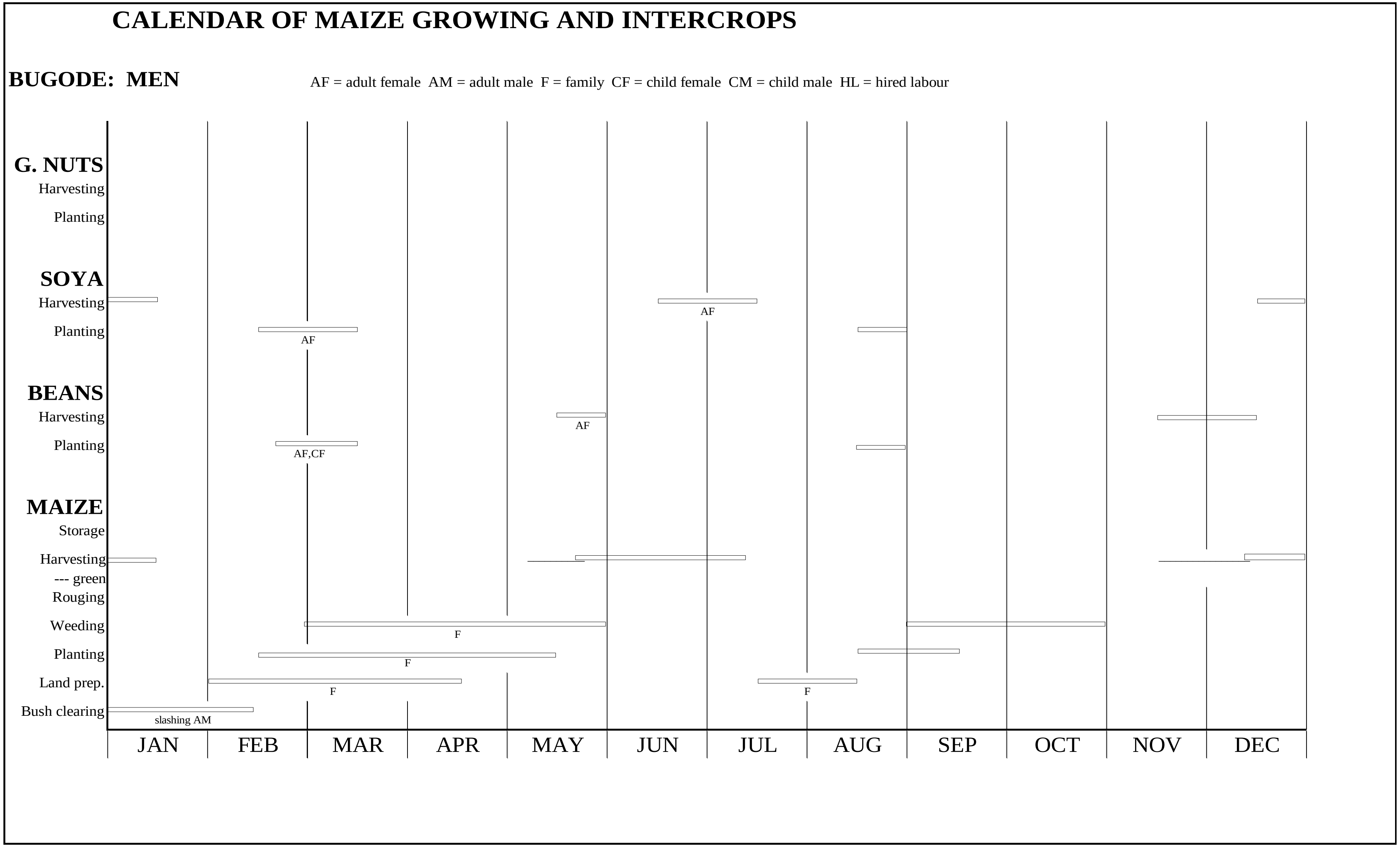
AF = adult female AM = adult male F = family CF = child female CM = child male HL = hired labour



APPENDIX 3 (cont)



APPENDIX 3 (cont)



APPENDIX 4 Details of maize varieties being grown and their origin in the study villages

	Mamukubembe				Bugodi			
	1997a	1997b	1998a	1998b	1997a	1997b	1998a	1998b
Local	50	26	32	40	50	33	33	26
Longe1 re-cycled	8	13	13	20	42	52	60	45
Longe1 original	38	56	38	38	4	15	7	13
Hybrid	3	3	2	2	0	0	0	3
Katumani	0	3	2	2	0	0	0	0
KWCA	0	0	0	0	4	0	0	6
None	3	0	13	13	4	0	0	6
	100	100	100	100	100	100	100	100
No. of responses	40	39	47	48	27	27	30	31

Table 1a. Planting of different maize seed types by season (percentage of responses)

	Mamukubembe				Bugodi			
	1997a	1997b	1998a	1998b	1997a	1997b	1998a	1998b
Local only	47	22	19	27	35	25	17	17
Longe1 only	36	67	42	46	39	63	58	46
KWCA	0	0	0	0	4	0	0	4
Hybrid (re-cycled)	0	0	0	0	0	0	0	4
Local & Longe1	8	3	19	24	13	13	25	17
Local, Longe1, Hybrid	6	3	0	0	0	0	0	0
Local & Katumani	0	3	0	0	4	0	0	0
Longe1 & hybrid	0	3	0	0	0	0	0	0
Longe1 & Popcorn	0	0	0	0	0	0	0	4
Longe1, hyb & Kat	0	0	3	0	0	0	0	0
None	3	0	17	3	4	0	0	8
No. of respondents	36	36	36	36	*23	24	24	24

* One farmer couldn't remember which maize seed was used in 1997a

Table 1b. Percentage of farmers growing combinations of maize seed types by season

APPENDIX 4 (cont)

Mamukubembe					Bugodi				
	1997a	1997 b	1998a	1998b		1997a	1997b	1998a	1998b
SG2000	16	12	8	10	District Ext.	0	17	5	0
Ujima	58	69	50	35	Demonstrations	46	28	30	0
Shop	0	4	8	10	Shop	0	0	10	22
Friends/ relatives	16	4	13	3	Friends/ relatives	8	22	15	11
Own	5	12	13	28	Own	23	17	20	39
FAO	0	0	8	0	St Ngondwe/ Byekwaso	15	17	20	28
Other	5	0	0	14	UNAFA	8	0	0	0

Table 1c. Sources of Longe1 seed (original and recycled) by season (percentage of responses from farmers growing Longe1)

APPENDIX 5

Farmers' problems, perceived causes and needs in maize production

TORORO DISTRICT

KISOKO	**MEN (RANKED PROBLEMS)**				**WOMEN (UNRANKED PROBLEMS)**			
Problem	**Cause**	**Farmer response**	**Farmer needs**		**Problem**	**Cause**	**Farmer response**	**Farmer needs**
Maize seed	All maize sold off Price (hybrid) too high Fake seed	Request seed from fellow farmers	Dept of Agri should avail good seed at reasonable price					
Inputs	Not available (e.g. storage chemicals) Not known about	Sell the maize before weevils become a problem	Good dist of inputs Training					
Land fertility	Over use of land due to scarcity	Crop rotation	-					
Labour	Lack of money to hire Sickness Community and intra family co-operation	-	Improved health services Unity/ community sensitisation					
Storage	Rats Theft	Rat poison Modern storage structures	Present problem to primary societies					
Marketing	Few buyers No fixed price							
Transport	Poor roads Lack of means of transport: farm to home home to market	-	Roads should be maintained locally					

APPENDIX 5 (cont)

AJUKET	MEN (RANKED PROBLEMS)				WOMEN (UNRANKED PROBLEMS)			
Problem	**Cause**	**Farmer response**	**Farmer needs**		**Problem**	**Cause**	**Farmer response**	**Farmer needs**
Stalk borers		Roguing	Knowledge of a chemical at a reasonable price		**Striga**	Late plating	-	Advice Chemicals
Striga	Lack of crop rotation Infertile soils Late planting	Crop rotation Weeding Adding cow dung Early planting	Technical advice		**Termites**	Anthills	-	Advice chemicals
Low yields	MSV	Roguing	Technical advice		**Molerats**		Bait; chemicals	Advice; chem.
Rotten grain	Ear rot	Poor grain used to feed pigs or used for waragi	Technical advice		**Stalk borer**		Roguing	Advice;chem
Soil fertility	Lack of crop rotation Continuous use of land Bush burning	Crop rotation Fallow Use of compost, manure	Technical advice on fertiliser use		**Drought**	-	-	-
Grain loss in storage	Storage pests Rats	Immediate sale Chem. control Proper drying Cats Rat poison	Affordable storage chemical or alternative		**Labour**	Lack of money	group work	
Shortage of labour	Lack of money	Use small area	Credit		**Soil fertility**	Erosion Cont. cultivation	-	Advice
Plants lost: towards maturity anytime	Termites Mole rats	Use of diazinon & ant killer Digging/trap	Technology Tech. advice		**Weevils**	Lack of chemicals/ knowledge	Sun drying store near smoke	Subsidy Advice on chemical to use
Low yielding varieties	Lack of varieties	-	Improved varieties		**MSV**	Insect within stem	Roguing	Research

APPENDIX 5 (cont)

IGANGA DISTRICT

MAMAKUBEMBE	**MEN (RANKED PROBLEMS)**				**WOMEN (UNRANKED PROBLEMS)**			
Problem	**Cause**	**Farmer response**	**Farmer needs**		**Problem**	**Cause**	**Farmer response**	**Farmer needs**
Soil fertility	Shallow cultivation Soil exhaustion Cutting of trees	Digging deeper Abandon land None	Tractor ploughs, large hoes Ferts., manure Tree pruning		**Poor germination**	Red ants	Gap filling	Seed dressing
Seeds	Poor seed selection	Selecting good cobs	?		**Drought**	Sunshine	wait for rains	-
Poor germination	Storage pests; rotten seeds Poor drying conds. Planting too deep	Planting many seeds/ hill Harvesting cobs early and hanging under trees in husks	Buying better quality seed		**Stem and shoot damage**	Insects and birds	Bird scaring and covering plant with grass	Assistance by spraying
Pale yellow leaves	MSV	Roguing	Tech. advice		**Seed eaten after planting**	Monkeys, guinea fowl, squirrels	Scaring	Learn to guard (organisation)
Birds eating seedlings	Associated with late planting	Timely planting	Sensitisation Tech. advice ?		**Cutting stem of maize**	Termites Mole rat	-	Chemicals Advice
Insect pests	Lack of insecticide	Pre-germinate seeds	Seed dressing		**Cob damage**	Monkey Ndiwulira	Scaring	Hunting Chemicals
Shelling		Beating with sticks	Shelling machines		**Storage**	Storage pests	Drying	?
Marketing	Low prices Poor storage	Reduce prod.	Reduce prod.		**Marketing**	Low prices	Just sell	High prices
Rotting in store	Poor storage	Sell off quickly	?		**Drudgery**	Hand hoe	-	Tractor Ox cultivation
Transport	Bad roads	Sell at low price	Repair roads		**White/ Yellow stripes**	Maize culture Disease Soils	Some rogue (when young); throw in bush	Spraying

APPENDIX 5 (cont)

BUGODE	**MEN (RANKED PROBLEMS)**				**WOMEN (UNRANKED PROBLEMS)**			
Problem	**Cause**	**Farmer response**	**Farmer needs**		**Problem**	**Cause**	**Farmer response**	**Farmer needs**
Land scarcity	Lack of money to buy/ hire land Increased pop.	Use less land	Means to increase land productivity		**Stem cutting**	Termites Mole rats	None or rogue Digging	Chemicals Chemicals
Lack of seed	Lack money Availability of quality seed	Plant local seed	Govt. to provide seed at reason-able prices		**No cob formation**	White stripes	Drying	Chemicals
Monkeys	Large tracts of unused land	Hunting	Game rangers to hunt them		**Grain damage**	Monkeys	Guarding Scaring	Kill monkeys
Termites	Ant-hills	Destroy anthills	Chemicals		**Stem, growing point & cob damage**	Stalkborer	-	Chemicals
Mole rats	Always been there	Trapping	Chemicals		**Storage losses**	Weevils	Drying	Chemicals
Soil fertility	Continuous usage	Rotation	Fertilisers		**Rotting**	Birds	Guarding	Kill birds
Stemborers/ Ndiluriwa	Unknown	Nothing	Resist. varieties; Chemicals		**Drudgery (trans. maize to home)**	Carrying load on head Hand threshing	-	Wheelbarrow Shellers
Loss in storage	Storage pests	Drying	Control chems. Resist. varieties		**Market**	Low price	Just sell	Market
Field theft	Poverty	Have thieves arrested	Stiff penalty for those caught		**Poor germination**	Red ants	Gap fill	Chemicals
Labour	Poverty	Create working groups	Govt to provide tractor hire		**Cob damage/ not forming**	Smuts	Pick and throw	Research
					Lodging of plant	Wind	-	-

APPENDIX 6

DISSEMINATION OF INFORMATION ON MSV THROUGH MEETINGS

Prior to the beginning of the 1st season's planting, in January 1997, meetings were held in all four study villages to explain MSV in some detail. The local agricultural officers attended the meetings. Farmers were also introduced to the idea of monitoring surveys to examine various aspects of farm management with regard to the incidence of MSVD. The following number of farmers attended the meetings:

Kisoko	79
Ajuket	48
Mamukubembe	79 (68 at beginning of meeting)
Bugodi	30
	236

The dissemination of the information on MSV took the form of a talk (through an interpreter) with the participation of farmers through questions and answers on their knowledge during the session as well as an opportunity for them to ask additional questions at the end. Care was taken throughout the talk not to make specific recommendations with regard to farming practices, rather to help farmers become aware of the practices which may increase or decrease the incidence of MSV and allow the farmers to form their own opinions of what to do about streak. The following aids were used for the talks:

1) four bottles containing examples of the MSV vectors (*Cicadulina mbila* and *C. storeyi* mixed) in alcohol in order to illustrate the size and shape of the insects
2) a healthy maize plant (7 leaf stage)
3) a maize plant infected at an early stage, to illustrate the nature of MSV and its severity
4) a maize plant infected at a later stage, to illustrate that symptoms only appear on leaves which grow after inoculation takes place.

In the talks at all the villages the following format was used:

1) show the streaking of the leaves (using a plant with MSV) and explain that it reduces the green area of the leaf which makes the plant grow less which then reduces the yield of the plant
2) the streaking is caused by a virus called maize streak virus and the virus cannot be cured once the plant has it
3) the virus is spread by a particular type of insect called a leafhopper (passing round the tubes of *Cicadulina*) which when it is feeding on a plant by sucking its juices can pick up the virus from an infected plant. Once the insect has the virus inside it, every time it feeds on another maize plant it may give that plant the virus. This is like a mosquito picking up the malarial parasite from one person and then passing malaria on to several other people. The virus cannot pass through the maize seed, only the leafhoppers can spread the virus by feeding on the plants
4) the insects are normally found in the wild grasses which they prefer to feed on and lay their eggs in

5) it is only the growing leaves that can get the virus so when a maize plant gets infected the leaves that have already grown do not show the streaking (show the later infected demonstration plant). The later a plant is infected by a leafhopper the less leaf area is lost due to streaking and the better the yield from the plant. A plant infected at a very early stage may die or not produce a cob at all
6) at the beginning of the growing season very few insects carry the virus, but as more and more maize plants get the virus the number of insects picking up the virus and spreading it increases. Late planted maize can get far more streaked plants than early planted because there are many more insects carrying the virus which can infect the plants
7) the insects prefer maize at a height of 25-40cm (demonstrated using hand above the ground) and it is at this time that MSV really starts to spread rapidly in the fields. With late planting the maize may be the only field at the preferred height in the area therefore more insects may collect in the field increasing the chances of more infection. Gap filling (replanting stands that have not germinated) will also increase the amount of streak because of the preference for the younger plants. This does not mean that gap filling should be stopped as most plants may still produce a yield of some sort, which is better than none at all from empty stands. For the same reason, roguing out diseased plants does not really help because there are many insects spreading the streak and plants which are rogued may have produced a yield
8) the insects that carry maize streak virus move close to the ground hopping from plant to plant in a maize field and are very active. It may be possible to make it more difficult for the insects to move around and reduce the amount of MSV by making the ground under the maize less open by planting with a dense intercrop such as beans or millet which reduces the movement of the insects
9) there are varieties of maize which are resistant to MSV. What this means is that although the maize still gets infected with the virus, the streak symptoms (the amount of green leaf lost due to the yellow streaking) are very much lower. Good resistant maize will show only a few dots of streaking on each leaf infected. This ensures that the area of green leaves is high and a good yield can be got from the plant. A variety developed in Uganda that shows good resistance to MSV and which is available from seed agents is Longe1 1, which is also resistant to other diseases and yields well. Another advantage of Longe1 1 is that it has a shorter growing period to reach maturity than local varieties.

APPENDIX 7
Examples of records taken when monitoring MSVD on farm

VILLAGE	PLOT NO.	FARMER	M/F	TYPE	MAIZE VAR	SPACING	SPACING A	PLANT DATE	PL DATE CODE	BEAN VAR	SPACING	IC PL DATE	NO. STANDS	ROWS* STANDS	NOTES	STANDS SAMPLED	PLANTS /STAND	TOTAL PLANTS	INFECTED PLANTS	% INFEC. PLANTS
KISOKO	7	NJIRA OCHWO	F	M	HYBRID	90*75	6750	2W/4	3				1000	50*20		160	1.7	272	3	1.10
KISOKO	8	CENTURIA OCHIEN	M	M	LONGE/L	100*75	7500	2W/4	3				1260	42*30	30-60	150	1.7	255	0	0.00
KISOKO	9	TOPHLY OBURU	M	M	LOCAL	100*90	9000	1W/4	2				600	30*20	NOT BEING WEEDED?	160	1.3	208	1	0.48
KISOKO	10	MICHAEL GARAMA	M	M	LONGE/L	100*90	9000	2W/4	3				1353	33*41		164	1.6	262	1	0.38
KISOKO	11	DESDERI OLOO	M	M	LOCAL	100*75	7500	8TH/4	3				768	24*32	SOME BEAN @ 1 M	160	1.9	304	0	0.00
KISOKO	12	OWARI NGUMA	M	M	HYBRID	100*90	9000	2W/4	3				810	45*18	60-90	144	1.8	259	0	0.00
KISOKO	13	JOSINE OMARA	M	M	LOCAL	100*75	7500	2W/4	3				775	25*31	SOME BEAN INTER 1MSPACE	155	1.7	264	0	0.00
KISOKO	14	ONYANGO YOKANA	M	M	LOCAL	100*75	7500	1W/4	2				2107	49*43	AFTER THIS GAP FILLED	172	2.1	361	3	0.83
KISOKO	16	OKONGO CHRISTOPHER	M	M	LOCAL	100*90	9000	2W/4	3				2108	62*34	50-70	136	1.7	231	1	0.43
KISOKO	17	FABIAN OKOTH	M	M	LOCAL	100*90	9000	2W/4	3				2009	41*49		196	1.9	372	0	0.00
KISOKO	18	JOPHY OWORI	M	M	LONGE	100*75	7500	2W/4	3				1116	31*36	50-70	144	1.4	202	0	0.00
KISOKO	19	OWERI OJALI	M	M	LOCAL	100*75	7500	2W/4	3				390	39*10	70-100	100	2.2	220	0	0.00
KISOKO	20	VALENTINO OKECHA	M	M	HYBRID	120*90	9000	2W/4	3				1344	42*32	50-80	128	1.7	218	1	0.46
KISOKO	21	OWERI OBOTH	M	M	LOCAL	100*75	7500	2W/4	3				864	36*24	50-80	144	2	288	0	0.00
KISOKO	22	MICHAEL OWERI	M	M	LOCAL	100*75	7500	3W/4	4				680	40*17	50-75	153	2.1	321	5	1.56
KISOKO	23	OKECHO CHRISTOPHER	M	M	LOCAL	100*75	7500	3W/4	4				860	43*20	50-80	140	1.5	210	1	0.48
KISOKO	24	NELSON OKECHO	M	M	HYBRID	100*75	7500	3W/4	4				6636	158*42	60-90 QUITE A LOT OF GAP FILLING	168	1	168	2	1.19
KISOKO	25	MICHAEL OWOI	M	M	LOCAL	90*75	6750	2W/4	3				868	31*28	60-100	152	1.3	198	0	0.00
KISOKO	26	ODOI LODOVIKO	M	M	LOCAL	100*75	7500	3W/4	4				1426	31*46	40-60	138	1.6	221	3	1.36
KISOKO	27	GARAMA OBOTH	M	M	HYBRID	100*75	7500	8-9TH/4	3				945	35*27	50-75	162	1.9	308	0	0.00
KISOKO	28	REMBO LINO	M	M	HYBRID	100*75	7500	2W/4	3				2064	48*43	SPACING VERY VARIABLE	172	1.7	292	4	1.37
KISOKO	29	BECHO LINO	M	M	HYBRID	100*100	10000	2W/4	3				462	21*22		154	1.7	262	1	0.38
KISOKO	30	JOSEPH OKONGO	M	M	LOCAL	100*90	9000	4W/4	5				1100	50*22	THEN TO 05??	110	1.4	154	1	0.65
KISOKO	31	GERRARD OPENDE	M	M	HYBRID	100*75	7500	4W/4	5				3360	105*32	15-20 2 WEEKS AFTER?	160	1.8	288	7	2.43
KISOKO	32	JOSEPH OWARI	M	I?	LONGE	100*60	6000	1W/5	6				1344	42*25	BEANS 1 ROW 1 M APART	150	1.9	285	0	0.00
KISOKO	33	ODOI LODOVIKO	M	M	LOCAL	120*90	10800	4W/4	5				2117	13*29		145	1.8	261	0	0.00
KISOKO	34	LAZARO ODOI	M	M	LOCAL	100*90	9000	4W/4	5				704	32*22	VERY VARIABLE	154	1.6	246	5	2.03
KISOKO	35	OLEANO OKOTH	M	?	LOCAL	100*75	7500	4W/4	5				1500	50*30		NOT	FOUND			
KISOKO	36	YAMU	M	I	LOCAL	100*75	7500	4W/4	5				1102	58*19		152	1	152	0	0.00
KISOKO	37	YAMU	M	M/I	LOCAL	100*75	7500	4W/4	5				1160	40*29		145	1.6	232	1	0.43
KISOKO	38	TABU NKUMO	M	M	LONGE/L	100*75	7500	4W/4	5				750	30*25		200	1.4	280	0	0.00
AJUKET	1	EMERAIT		M	LOCAL	90*75	6750	15-Apr	4				3978	34*117		150	2.9	435	1	0.23
AJUKET	2	RAPHAEL OTWANI	M	M	LOCAL	100*80	8000	09-Apr	3				1400	50*28	2 MSV. SHADED TO LINE OF BANANA	140	2.8	392	3	0.77
AJUKET	3	JOPHYRY AMAI	M	M	LOCAL	100*90	9000	11-Apr	3				1650	55*30		150	2.9	435	0	0.00
AJUKET	4	DAVID WAKESA	M	M	LOCAL	100*90	9000	17-Apr	4				759	69*11	SOME BANANAS. 100*75	143	2.7	386	1	0.26
AJUKET	5	DAVID WAKESA	M	M	LOCAL	100*80	8000	17-Apr	4				1485	54*27	SOME CASSAVA. ALL HAD ACMV	162	2.6	421	0	0.00
AJUKET	6	DAVID WAKESA	M	M	LOCAL	100*80	8000	17-Apr	4				1404	54*26	CONTINUE FROM ABOVE NO CASSAVA	156	2.7	421	3	0.71
AJUKET	7	JOSEPH ETIANG	M	M	LOCAL	90*80	7200	18-Apr	4				1425	25*57	GREENGRAM PLANTED IN SAME HOLE	171	2.5	428	2	0.47
AJUKET	8	ALEX WAMALWA	M	M	LOCAL	100*80	8000	20-Apr	4				2160	45*48	SOME CASSAVA. AW CATERPILLAR	144	?		0	0.00
AJUKET	9	JOSEPH OBUKUI	M	M	LOCAL	100*75	7500	01-May	6				5500	55*100		150	1.6	240	1	0.42
AJUKET	10	LISIANG	F	M	LOCAL	100*70	7000	14-Apr	3				1100	25*44	A FEW GRAMS	132	2.1	277	0	0.00
AJUKET	11	EKISA SAMPSON		M	LOCAL	90*70	6300	01-May	6				5665	55*103		150	1.9	285	2	0.70
AJUKET	12	KEREMENTE OPERO	M	M	LOCAL	90*90	8100	14-Apr	3				2079	27*77	BEANS IN SAME HOLE *STOPPED 1/2 WAY	150	2.2	330	1	0.30

APPENDIX 7 (cont)

VILLAGE	PLOT NO.	FARMER	M/F	TYPE	MAIZE VAR	SPACING	SPACING A	PLANT DATE	PL DATE CODE	BEAN VAR	SPACING	IC PL DATE	NO. STANDS	ROWS* STANDS	NOTES	STANDS SAMPLED	PLANTS /STAND	TOTAL PLANTS	INFECTED PLANTS	% INFEC. PLANTS
AJUKET	13	DISMUS EMAGRO		M	LOCAL	100*80	8000	10-Apr	3				2220	30*74	SOME BEANS @ 1*1	150	2.9	435	0	0.00
AJUKET	14	DISMUS EMAGRO		M	LOCAL	100*80	8000	10-Apr	3				851	37*23	MSV. NB SOME SORGHUM	161	2.8	451	0	0.00
AJUKET	15	LISA ETIANG	F	M	LOCAL	100*80	8000	01-May	6				440	22*20	CORNER OF ANOTHER OLDER PLOT	160	2	320	0	0.00
AJUKET	16	LAWRENCE OMWENI	M	M	LOCAL	100*75	7500	14-Apr	3				1404	26*54	SOME SWEET POT + BEANS ONE END	162	1.8	292	0	0.00
AJUKET	17	LAWRENCE OMWENI	M	M	LOCAL	100*100	10000	17-Apr	4				544	32*17	SOME SWEET POTATO	153	2.9	444	0	0.00
AJUKET	18	LAWRENCE OMWENI	M	M	LOCAL	120*100	12000	17-Apr	4				390	26*15	PATH IN BETWEEN PLOT 17	150	2.8	420	1	0.24
AJUKET	19	MATEUS ETIANG	M	M	LOCAL	100*75	7500	17-Apr	4				1342	22*61		150	2.5	375	2	0.53
AJUKET	20	JOSEPH OKORIMO	M	M	LOCAL	90*60	5400	17-Apr	4				2400	30*80	CASSAVA STICKS READY TO GO IN	150	2	300	1	0.33
AJUKET	21	MATEUS ETIANG	M	M	LOCAL	100*75	7500	17-Apr	4				1265	23*55		155	2.7	419	9	2.15
AJUKET	22	MATEUS ETIANG	M	M	LOCAL	100*90	9000	17-Apr	4				1375	25*50	(TO TREE) SOME CASS.& SWEET POT.	150	2	300	7	2.33
AJUKET	23	NAFUTALI OUMA		M	LOCAL	100*100	10000	01-May	6				320	16*20		120	3.4	408	2	0.49
AJUKET	24	WANYONYI OKWENI		M	LOCAL	100*80	8000	14-Apr	3				595	35*17		153	1.9	291	0	0.00
M'BEMBE	1	GRACE BAKERA	F	M	LONGE	100*90	9000	02-Apr	2				759	33*23		161	2.5	403	1	0.25
M'BEMBE	2	GRACE BAKERA	F	M	LOCAL	130*75	9750	03-Apr	2				480	16*30	NEEDS WEEDING	150	2.9	435	1	0.23
M'BEMBE	3	GRACE BAKERA	F	M	LONGE	120*80	9600	02-Apr	2				980	35*28	JUST WEEDED 3 MSV 1 MSV THINNED	140	1.9	266	3	1.13
M'BEMBE	4	GRACE BAKERA	F	I	LOCAL	100*75	7500	10-Apr	3	K132	30*30	10-Apr	420	20*21		147	3.8	559	35	6.27
M'BEMBE	5	IRENE NABUMASI	F	M	LOCAL	100*90	9000	05-Apr	2				840	30*28	NEEDS WEEDING. 3 MSV	140	3.2	448	5	1.12
M'BEMBE	6	FLORENCE KAGWERI	F	M	LONGE	100*75	7500	01-Apr	2				1200	30*40	HALF BADLY WEEDED. 8 MSV	160	2.8	448	5	1.12
M'BEMBE	7	JOYCE NAKISIGE	F	M	LOCAL	120*90	10800	04-Apr	2				900	25*36		144	3.9	562	1	0.18
M'BEMBE	8	MOSES KABULU	M	M	LOCAL	120*90	10800	02-Apr	2				910	35*26	2 MSV	156	2.2	343	4	1.17
M'BEMBE	9	ZAWULENSI NABUGULU	F	M?	LOCAL	120*90	10800	29-Mar	1				551	19*29	SOME BEANS LATE PLANTED	145	2.7	392	1	0.26
M'BEMBE	10	IRENE NABUMASI	F	M	LONGE	100*80	8000	08-Apr	3				602	43*14	2 MSV	154	1.9	293	2	0.68
M'BEMBE	11	MUTESI MIRABU	F	M	LONGE	100*80	8000	03-Apr	2				1260	42*30	3 MSV	150	1.9	285	3	1.05
M'BEMBE	12	JANET BALYEKU	F	M	LONGE	90*80	7200	03-Apr	2				1152	32*36	4 MSV	144	1.4	202	2	0.99
M'BEMBE	13	ANDRE KAPERE	M	M?	LONGE	100*75	7500	20-Apr	4				1058	23*46	LOT OF MSV. SOME BEANS	138	2.3	317	13	4.10
M'BEMBE	14	GRACE BASALIRWA	F	M	LOCAL	120*90	10800	05-Apr	2				1080	18*60	1 MSV	150	2.4	360	0	0.00
M'BEMBE	15	HUSSEIN KAGULYA	M	M	LONGE	120*80	9600	29-Mar	1				1040	26*40	4 MSV	160	2.1	336	2	0.60
M'BEMBE	16	ISABI?? KIROVESI	M	I	LOCAL	200*90	18000	27-Mar	1	K131	25*25	01-Apr	266	14*19	OUT TO ROAD	152	3.2	486	8	1.64
M'BEMBE	17	ISABIRI SABASI	M	M	LOCAL	150*100	15000	25-Mar	1				336	21*16	2 MSV	128	2.8	358	4	1.12
M'BEMBE	18	JANET BUBUGA	F	M	LONGE	100*90	9000	30-Mar	1				272	16*17	2 MSV	153	1.9	291	4	1.38
M'BEMBE	19	JANET BUBUGA	F	M?	LOCAL	120*90	10800	10-Apr	3				100	10*10	VERY YOUNG GROUNDNUTS	100	3.9	390	4	1.03
M'BEMBE	20	THOMAS KALENZI	M	I	LOCAL	200*90	18000	04-Apr	2	KANYCHWA	25*25	07-Apr	540	20*27		162	3.8	616	7	1.14
M'BEMBE	21	YUABI MWIMA	M	M	LOCAL	200*90	18000	04-Apr	2				176	16*11		154	3.7	570	1	0.18
M'BEMBE	22	MOSES MAMY	M	I	LOCAL	200*90	18000	10-Apr	3	K20	25*25	10-Apr	330	22*15		150	2.9	435	3	0.69
M'BEMBE	23	BABIRYE MWAJUMA	F	I	LOCAL	150*90	13500	29-Mar	1	KANYCHWA	25*25	03-Apr	260	13*20	1 MSV	160	2.4	384	64	16.67
M'BEMBE	24	JAMES ZIGWANA	M	M	LOCAL	150*90	13500	06-Apr	2				468	18*26		156	4.5	702	3	0.43
M'BEMBE	25	MOSES SANDE	M	M	LOCAL	150*90	10800	10-Apr	3				414	18*23		161	3.7	596	7	1.18
M'BEMBE	26	MRS MWIMA	F	M?	LOCAL	200*90	18000	04-Apr	2				390	13*30	MILLET JUST EMERGING	150	3	450	0	0.00
M'BEMBE	27	MRS WAKABI	F	I	LOCAL	150*90	13500	04-Apr	2	WHITE HARICOT	25*25	10-Apr	150	15*10		150	3.9	585	1	0.17
M'BEMBE	28	VINCENT BALABA	M	I	LOCAL	150*90	13500	10-Apr	3	KANYCHWA	25*25	13-Apr	486	18*27		162	3.1	502	5	1.00
M'BEMBE	29	MR MAYANDA	M	I	LOCAL	200*90	18000	04-Apr	2	BLACK BEANS	5 ROWS	13-Apr	247	13*19		152	3	456	2	0.44

APPENDIX 7 (cont)

VILLAGE	PLOT NO.	FARMER	M/F	TYPE	MAIZE VAR	SPACING	SPACING A	PLANT DATE	PL DATE CODE	BEAN VAR	SPACING	IC PL DATE	NO. STANDS	ROWS* STANDS	NOTES	STANDS SAMPLED	PLANTS /STAND	TOTAL PLANTS	INFECTED PLANTS	% INFEC. PLANTS
M'BEMBE	30	MR MAYANDA	M	M	LONGE	100*80	8000	29-Mar	1				990	33*30	FERTILIZER @ 2 WEEKS	150	1.8	270	4	1.48
BUGODE	1	KAITUKA	M	M	LOCAL?	100*80	8000	02-Apr	2				406	14*29		145	3	435	0	0.00
BUGODE	2	PATRICK IMUNTO	M	I	LONGE?	200*90	18000	02-Apr	2	K131+MIX	5 ROWS	02-Apr	260	10*26		156	2.9	452	0	0.00
BUGODE	3	MOSES NKANGA	M	I	LOCAL	150*80	12000	EARLY 4	2	K131+MIX	5 ROWS	EARLY 4	532	14*38	SHADED	190	2.1	399	1	0.25
BUGODE	4	NGOBI	M	I	LOCAL	150*80	12000	EARLY 4	2	K131+MIX	5 ROWS	EARLY 4	460	23*20	MSV	160	4	640	2	0.31
BUGODE	5	JOSEPHINE MUKYALA	M	I	LOCAL	150*90	13500	EARLY 4	2	K131+MIX	5 ROWS	EARLY 4	224	16*14		154	2.3	354	9	2.54
BUGODE	6	NABIRYE	F	I	LOCAL	150*80	12000	EARLY 4	2	LOCAL	5 ROWS	EARLY 4	300	12*25		200	3	600	19	3.17
BUGODE	7	NABIRYE	F	M?	LOCAL	200*80	16000	EARLY 4	2			EARLY 4	308	14*22	LATE PLANTED GROUNDNUT	154	3.1	477	6	1.26
BUGODE	8	NABIRYE	F	I	LOCAL	200*90	18000	EARLY 4	2	LOCAL	25*25	EARLY 4	936	26*36		144	2.1	302	18	5.95
BUGODE	9	PERUSI	F	I	LOCAL	150*90	13500	EARLY 4	2	LOCAL	25*25	EARLY 4	456	19*24		192	2	384	11	2.86
BUGODE	10	NABIRYE	F	I	LOCAL	150*80	12000	EARLY 4	2	LOCAL	25*30	EARLY 4	221	13*17		153	3.4	520	0	0.00
BUGODE	11	MANGARITA	F	M?	LOCAL	200*90	18000	EARLY 4	2			EARLY 4	323	17*19	LATE GROUNDNUT	152	2.8	426	2	0.47
BUGODE	12	MANGARITA	F	M	LOCAL	120*75	9000	EARLY 4	2			EARLY 4	328	8*41	1 WIDE ROW BEANS	164	3.3	541	3	0.55
BUGODE	13	MRS BUYEKWASO	F	M	LONGE	100*75	7500	EARLY 4	2			EARLY 4	288	9*32		160	2.1	336	2	0.60
BUGODE	14	MRS BUYEKWASO	F	I?	LONGE	100*75	7500	EARLY 4	2	K131	1 ROW OF 3	EARLY 4	352	11*32		160	1.8	288	1	0.35
BUGODE	15	MRS BUYEKWASO	F	M	LONGE	100*75	7500	EARLY 4	2			EARLY 4	920	23*40		160	1.9	304	4	1.32
BUGODE	16	LOYI KUBANAKU	F	M	LOCAL	200*80	16000	EARLY 4	2			EARLY 4	240	16*15	SOME SCATTERED MILLET	150	3.8	570	5	0.88
BUGODE	17	MRS KIRANDA	F	I	LOCAL	200*80	16000	EARLY 4	2	LOCAL	25*30	EARLY 4	396	18*22		154	3.2	493	0	0.00
BUGODE	18	LOYI KUBONAKU	F	I	LOCAL	150*80	12000	EARLY 4	2	LOCAL	25*25	EARLY 4	405	15*27		162	3.8	616	7	1.14
BUGODE	19	CHARLES KISEKE	M	M	LOCAL	100*80	8000	EARLY 4	2			EARLY 4	90	9*10	LATE SOYA	90	3.4	306	0	0.00
BUGODE	20	CHARLES KISEKE	M	M	LOCAL	120*90	10800	EARLY 4	2			EARLY 4	176	16*11	LATE SOYA	154	2.7	416	0	0.00
BUGODE	21	MAWAZI BASOGA	M	M	LONGE	100*90	9000	EARLY 4	2			EARLY 4	299	13*23		161	2.8	451	1	0.22
BUGODE	22	SEOVIA KISEKE	F	M	LOCAL	100*80	8000	EARLY 4	2			EARLY 4	1200	30*40		160	1.9	304	4	1.32
BUGODE	23	SEOVIA KISEKE	F	M	LOCAL	200*90	18000	EARLY 4	2	LOCAL	25*30	EARLY 4	286	13*22	SOME CASSAVA	154	2.7	416	8	1.92
BUGODE	24	FALIDA NANTALE	F	I	LOCAL	200*90	18000	EARLY 4	2	LOCAL	25*25	EARLY 4	252	14*18		144	4	576	4	0.69
BUGODE	25	MARIKI NGANDA	M	M	LONGE	150*90	13500	EARLY 4	2			EARLY 4	252	18*14		154	3	462	19	4.11
BUGODE	26	SULAINA KAGOYA	F	M	LONGE	150*100	15000	EARLY 4	2			EARLY 4	378	21*18	SOME PADDY RICE	144	3	432	7	1.62
BUGODE	27	SABANI NAMPALA	M	I	LOCAL	200*100	20000	EARLY 4	2	LOCAL	25*25	EARLY 4	315	21*15		150	2.8	420	3	0.71
BUGODE	28	HADIJA MUYINGO	F	I	LOCAL	200*90	18000	EARLY 4	2	LOCAL	25*30	EARLY 4	442	17*26		156	2.7	421	5	1.19
BUGODE	29	PETER DHIKUSOOKA	M	I	LOCAL	200*80	16000	EARLY 4	2	LOCAL	25*25	EARLY 4	238	17*14		154	2.9	447	12	2.69
BUGODE	30	JOHN KASIRYE	M	M	LONGE	100*90	9000	EARLY 4	2			EARLY 4	384	16*24	1 ROW OF YOUNG BEANS @ 1-1.5 M	144	1.9	274	3	1.10

APPENDIX 8

Information sheets in English and Luganda

APPENDIX 9

Details of the MSV workshop held in March 1999:

1. The purpose of the workshop
2. The workshop programme
3. A list of the 34 participants.

1.

MAIZE STREAK VIRUS PROJECT

WORKSHOP TO BE HELD on 2nd and 3rd March 1999

AT THE SUNSET HOTEL, JINJA

PROGRAMME

The workshop will focus primarily on the problems associated with maize streak virus disease (MSVD) as a constraint to smallholder maize production but will also be an opportunity to review the importance of MSVD in the pest and disease complex in maize-based cropping systems in the region.

The objectives of the workshop are to

- disseminate the results of the NARO/NRI collaborative research on MSVD epidemiology and vector ecology
- enable key workers in the region to exchange experiences and ideas on the control of MSVD from their country's or organisation's perspective
- identify opportunities and researchable constraints to increasing sustainable production of maize by smallholders in Uganda.

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Monday 1st March

Arrival at Sunset Hotel, Jinja
Registration

…………………………………………………………………………………………………

Tuesday 2nd March: **Morning session**

Chairperson: Director NAARI

09.00 Opening Session

09.00 Introduction to the workshop. Prof R Cooter, NRI

09.15 Remarks by the RDC Jinja

09.45 Opening address: Director General, NARO

10.15 Announcements

Rapporteur: Dr J Kikafunda

10.30-11.00 Coffee

Plenary Session

Maize: Research priorities and experiences

Chairperson: Prof R Cooter

11.00 Country situation reports on maize production

Speakers are asked to outline, in a short presentation, (a) The position and nature of maize production in their country (b) research priorities and experiences in tackling these (c) the agriculture science system, how funded ,its sustainability, and the links between research and extension (d) the role of socio-economics including interaction between researchers and the farmers

11.00 - 11.30 Presentations from:

Uganda	Dr D Kyetere
	SJ Wandera
Kenya	Dr F Ndambuki
South Africa	Dr M Barrow

11.30 The maize streak virus disease problem

11.30 Introduction to MSVD Mr W Page

11.50 - 12.30 The MSVD problem and current solutions in:

Kenya Dr F Ndambuki
South Africa Dr M Barrow
Uganda Dr G Bigirwa

12.30 Discussion

Rapporteur: Dr C Changa

13.00-1400 Lunch

Tuesday 2nd March: Afternoon session

Chairperson: Dr D Kyetere

14.00 Maize streak virus disease: Research and approaches to a solution

14.00 Vectors of MSVD and their behaviour within maize plots Mr W Page
14.20 Vector behaviour in relation to MSVD epidemiology and crop losses
Mr W Page
14.40 Current research at ICIPE Dr K Ampong-Nyarko
Breeding for MSV resistance, experiences from:
15.00 CIMMYT Dr D Kyetere
15.20 South Africa Dr M Barrow
15.40 Uganda Dr D Kyetere

16.00-16.30 Tea

16.30 Farmer maize growing practices in relation to MSVD incidence Mr W Page
16.50 Access to maize seed: towards empowering the farmer Mr R Lamboll
17.10 Synthesis of the session Prof M Thresh

17.30-18.00 Discussion

Rapporteur: Mr E Okoth
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Wednesday 3rd March: Morning session

Chairperson: NARO/MEPU representative

08.30 Constraints and opportunities for sustainability

Speakers are asked to discuss constraints and opportunities within their work on maize production, including any experiences with maize streak virus disease.

From the farmer's perspective

08.30 MSV Project: On farm surveys — Mr R Lamboll, Mrs G Bakaira

From the seed producer's perspective

09.15 Ugandan Cereals Programme — Dr D Kyetere
09.30 Kenya Seed Company — Mr J Ndemo
09.45 Maize seed production (Uganda Seed Project) — Mr W Mangheni
10.00 Maize seed production (S. Africa) — Dr M Barrow
10.15 FOSEM — Mr E Okoth

10.30 Discussion

11.00-11.15 Coffee

From the development and extension perspective

11.15 IDEA — Mr M Wood
11.35 NASECO — Mr F Bagonza
11.55 IPM/CRSP — Dr G Bigirwa
12.25 Extension Services — Mr J Dhikusooka (Iganga District)

12..45 Discussion

Rapporteur: Miss F Kyazze

13.00-14.00 Lunch

Wednesday 3rd March: Afternoon session

14.00 - 16.00 Working Groups

Suggested topics:

1. The role of stakeholders in maize technology development and transfer.

2. Sustainability of community-based maize seed production.

16.00-16.30 Tea

Chairperson: Mr W Page

16.30 Group presentations
17.00 General discussion
18.00 Synthesis of the workshop — Prof M Thresh

18.30 Closing address LC5 Chairman, Jinja

Rapporteur: Dr D Kyetere

Bites and drinks before dinner

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Thursday 4th March

Leave hotel

…………………………………………………………………………………………

3.

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